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(AGRICULTURAL RESEARCH SECTION)

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NOTICES

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NOTES ON THE VEGETATION AND THE FLORA OF MOUNT AUGUSTUS, BULLER COUNTY

By R. MASON and N. T. MOAR, Botany Division, Department of Scientific and Industrial Research, Christchurch

(Received for publication, 7 July 1955)

Summary

The vegetation and the flora of an area lying between 2,000 and 2,800 ft. on the north-eastern slopes of Mount Augustus, Papahaua Range, Buller County, were examined.

The gullies for the most part were clothed in bush of trees and shrubs 15 to 20 ft. high. The interfluvial slopes were either covered with peaty soil two-feet deep, in places eroding, on which *Danthonia rigida* var. *teretifolia* and *Hypolaena lateriflora* were dominant, or had a surface of bare gritstone rock with low shrubs and herbs in the crevices. Fires over a long period have burnt much of the peaty soil down to the bare rock.

The area is not rich floristically. A number of plants not hitherto recorded from the district were noted; also several were recorded at a higher altitude than that at which they have been previously found in the district. No naturalized plants were found amongst the indigenous vegetation.

INTRODUCTION

In the course of field work in the Westport district in January–February, 1953, two days were spent on the plateau sloping down from Mount Augustus towards Stockton in order to make a complete list and a comprehensive collection of plants occurring there. The routes followed are marked on the accompanying map (Fig. 1). The open-cast coal mining which was commenced in this district in recent years will eventually destroy the present land surface, and with it the vegetation. Although one or two plant specimens had been previously collected from Mount Augustus there is no published account of the area.

Mount Augustus (3,316 ft.) is part of the Papahaua Range, which has been described by Morgan and Bartrum (1915) as a distorted plateau consisting of granite, gneiss, and Paleozoic sedimentary rocks capped in most cases by Tertiary coal measures. The seaward side of the range falls steeply to the coast, but the inland side slopes gradually to the east. The surface is dissected by streams which have cut steep-sided gullies of varying depth in the hard grit or sandstone overlying the coal measures.

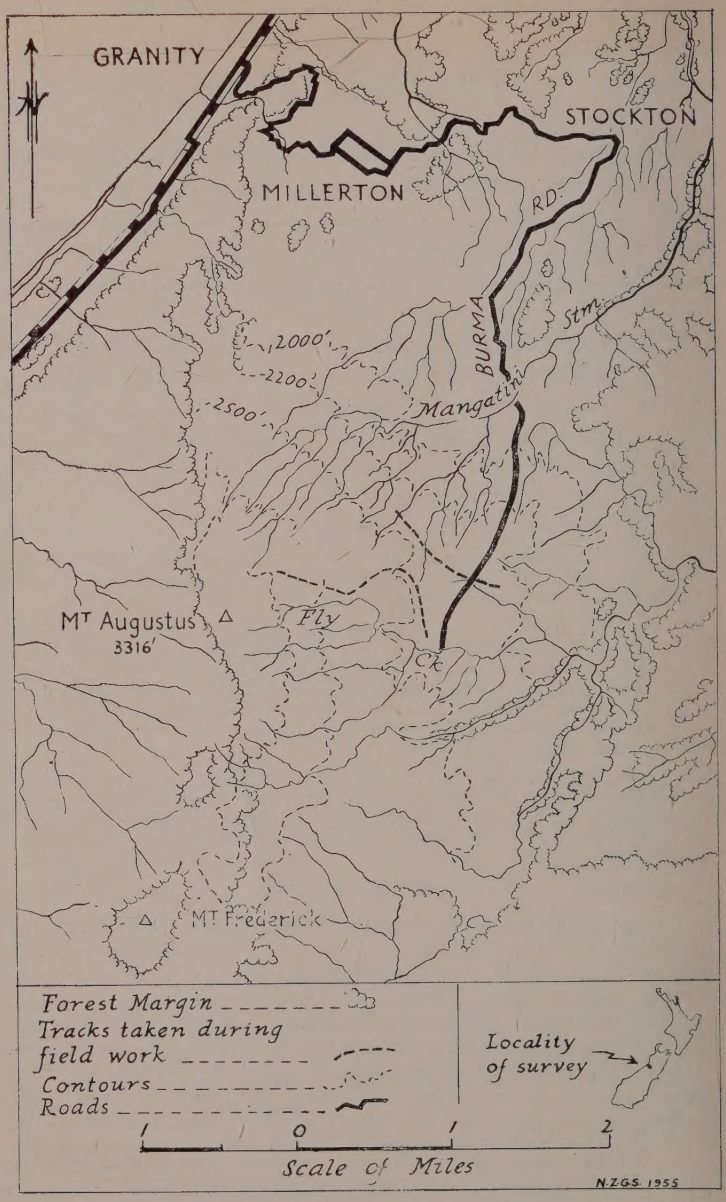

Fig. 1.—Mount Augustus, Buller County (Topographical Map S24, 324822). The area examined is indicated by the routes marked.

Fig. 2.—Looking toward the sea at about 3,000 ft. *Leptospermum scoparium* in foreground, with *Phormium colensoi* at the foot of the slope. A rough road crosses the nearest gully. *Danthonia rigida* var. *teretifolia* and *Hypolaena lateriflora* occur between the first and second gullies.

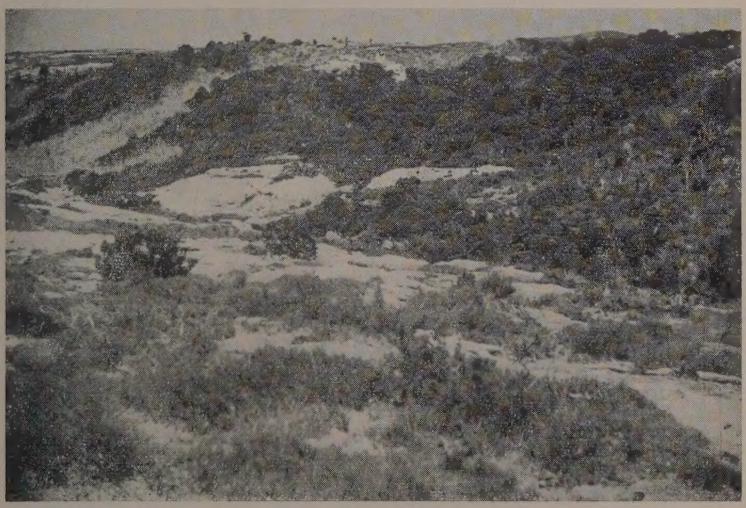

Fig. 3.—Gully at about 2,000 ft. Trees are: *Metrosideros umbellata, Dacrydium intermedium, Nothopanax colensoi, Nothofagus cliffortioides,* and *Weinmannia racemosa.* An old burn can be seen on the gully face to the right, and a more recent one is seen on the left.

(Fig. 2) The open-cast coal mine is situated above 2,000 ft. near Fly Creek. Access to it is through Millerton and Stockton and then by the Burma Road.

The vegetation of the plateau has been modified by fires. Between Mount Augustus and Millerton there is an area devoid of vegetation owing to fire in an abandoned coalmine which has been burning for many years. Smoke is usually visible rising from the mine, and the surface of the ground is reported to be always hot. The part visited has at some time in the past been affected by fires to the extent that over wide areas not only the vegetation, but also the peaty soil has been destroyed. Weathered remains of shrubby plants lying on interfluvial slopes and dead, burnt, standing shrubs on some gully slopes (Fig. 3) are relics of the fires.

There are no previously published records of the vegetation of Mount Augustus. So far as the authors are aware there is from there only one herbarium specimen, that of *Coprosma retusa* in the Dominion Museum collected by P. G. Morgan. Townson visited Mount Frederick (3,620 ft.) two miles to the south, Mount William (3,490 ft.) six and one half miles to the south, and Mount Rochfort (3,417 ft.) nine and one half miles to the south-west. His records are included in his "On the Vegetation of the Westport District" (1907). Petrie (1914) published some further records for Mount Rochfort after a visit subsequent to Townson's paper. These are the only botanical records of vegetation of the higher levels of the Papahaua Range.

The average annual rainfall in the district is high, that for Millerton about three miles from Mount Augustus being nearly 131 in. Strong winds are not so prevalent at low altitudes as in other parts of New Zealand, but higher regions such as Mount Augustus are subject to strong winds. Fog is prevalent on the elevated country near Denniston and Millerton during the greater part of the year, but is less frequent during the winter months.

VEGETATION

The eastern slope of Mount Augustus is of barren aspect with much exposed rock alternating with patches of shallow peaty soil bearing stunted vegetation. Vegetation is best developed in gullies where forest species often form a dense canopy.

Gullies

The vegetation, varying in density from gully to gully, consisted in most cases of trees and shrubs 15 to 20 ft. high which formed a closed canopy. There were some gullies, however, in which forest vegetation was absent. In those forested gullies examined *Metrosideros umbellata, Nothopanax colensoi, Pseudopanax lineare, Suttonia divaricata,* and *Phyllocladus alpinus,* were common. *Nothofagus cliffortioides* was present in one gully at 2,500 ft. The vegetation near the head of a forested gully and that of a non-forested gully are described in detail.

Forested Gully: Metrosideros umbellata, Dacrydium intermedium, and *Pseudopanax lineare* were common on the floor of this gully where there was also one plant of *Archeria traversii.* There was almost no herbaceous ground layer, but a few plants of *Blechnum minus, Craspedophyllum armstrongii, Enargea parviflora,* and *Astelia cockaynei*

were growing in shallow soil. Shrubs such as *Coprosma foetidissima* and *Suttonia divaricata* grew at the base of the cliffed edge. The steep sides were dominated by *Metrosideros umbellata,* but *Nothopanax colensoi, Nothopanax colensoi, Pseudopanax lineare, Suttonia divaricata,* and *Dacrydium intermedium* formed dense growth near the top of the gully side (Fig. 4).

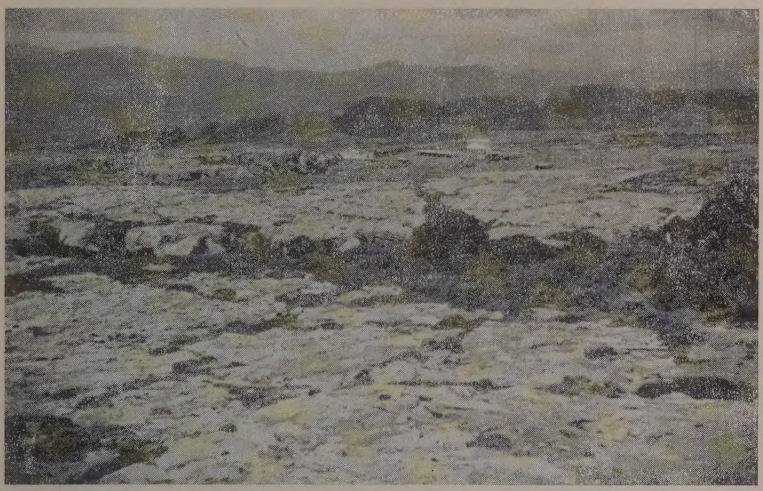

Fig. 4.—Looking across a gully at about 2,600 ft. towards the open-cast coal mine and the Ngakawau valley. Gritstone with vegetation in crevices. The tree tops showing above gully are *Metrosideros umbellata. Leptospermum scoparium* and *Dracophyllum longifolium* at the gully edge.

Non-forested Gully: Dacrydium biforme, about 4 ft. high, was present on the rock floor of the gully, and in situations close to pools of water were *Leptopteris hymenophylloides, Grammitis billardieri,* and *Drosera stenopetala.* Small, dense patches of *Danthonia australis* were growing in shallow soil in the shadow of the rocks. A few plants of dwarf *Metrosideros umbellata* were growing in crevices on the steep rock sides and isolated plants of *Forstera mackayi* and *Celmisia sessiliflora* were growing on damp faces and narrow ledges. Other plants present included *Leptospermum scoparium* and *Dracophyllum uniflorum; Pimelea gnidia* was growing at the edge of the gully.

Interfluvial Slopes

Vegetation of the interfluvial slopes was in marked contrast with the tall, dense vegetation of the forested gullies. There were here two different types of vegetation, that of shallow peaty soil and that of the rocks. For the most part the vegetation of the rocks must be secondary and subsequent to the disappearance of an original peaty cover. Much of the peaty soil is still eroding.

Vegetation of Peaty Soil. Two areas of shallow peaty soil were examined. The soil on each was no more than two feet deep.

The first at an altitude of about 2,600 ft. was extensive and lay on a large undissected slope between two gully systems. The soil was eroding in some places, and in parts the underlying grit or sandstone had been exposed. This area, which was dominated by *Danthonia rigida* var. *teretifolia* and *Hypolaena lateriflora*, had a few scattered clumps of stunted shrubs severely trimmed by the prevailing winds. Species associated with the two dominants usually included *Lycopodium ramulosum*, *Carpha alpina*, *Gleichenia circinata* var. *alpina*, *Donatia novae-zelandiae*, *Gentiana townsoni*, and *Astelia linearis*. The few clumps of shrubs were composed of *Dracophyllum uniflorum*, *Elaeocarpus hookerianus*, *Pseudopanax lineare*, and *Exocarpus bidwillii*. Associated with these shrubs and sheltered by them were *Pentachondra pumila*, *Cyathodes empetrifolia*, *Drapetes dieffenbachii*, and *Coprosma foetidissima*. Shallow hollows are formed in the soil by erosion and the muddy bottoms of these are frequently covered by *Liparophyllum gunnii*. (Fig. 5).

Fig. 5.—Vegetation on shallow peaty soil; mainly *Danthonia rigida* var. *teretifolia* and *Hypolaena lateriflora*. The hollow with cracked mud is a suitable habitat for *Liparophyllum gunnii*. A low clump of bushes, listed in the text, is seen at the right near the sky-line. The dark shrub on the sky-line is *Metrosideros umbellata*. Dead branches are remains of *Dacrydium biforme*.

The second was near the roadside at about 2,000 ft. and was about a quarter of an acre in extent. Here *Hypolaena lateriflora* was dominant with occasional plants of *Leptospermum scoparium* and *Dracophyllum densum* growing above the general level of the *Hypolaena*. *Danthonia rigida* var. *teretifolia* was present and in a few places locally dominant. Other species were *Dacrydium biforme*, *Cyathodes empetrifolia*, *Pentachondra pumila*, *Lycopodium ramulosum*, *Drosera spathulata*, *Carpha alpina*, *Oreobolus pectinatus*, and *Senecio bellidioides*. Here, also, small areas were eroding and in these *Gaimardia ciliata*, *Actinotus suffocata*, and *Donatia novae-zelandiae* were growing. At the lower edge of this second area there was a narrow stream bed of muddy sand and

grit. At the junction of the peaty soil and sand, *Euphrasia wettsteiniana,* in flower and early stages of fruit, was growing in extensive patches, and *Oreobolus pectinatus, Donatia novae-zelandiae, Actinotus suffocata,* and *Drosera spathulata* also occurred. In the muddy sand there were widely scattered clumps of *Juncus antarcticus, J. planifolius, J. effusus, Scirpus aucklandicus* var. *subcucullatus,* and *Scirpus* aff. *merrillii.* Dead branches and shrubs of *Dacrydium biforme* were present on both areas, but particularly on the first. (Fig. 6).

Fig. 6.—Patches of *Euphrasia wettsteiniana* in flower at the junction of the peaty soil and muddy sand. *Hypolaena lateriflora, Leptospermum scoparium,* and *Danthonia rigida* var. *teretifolia* on peaty soil. Remains of *Dacrydium biforme* in right background.

Rock Vegetation. Much of the slope was bare of vegetation except for scattered shrubs of *Dracophyllum densum, Leptospermum scoparium,* and herbaceous plants such as *Gahnia* sp. and *Carpha alpina.* Vegetation was in such places confined to shallow soil in small depressions and to long narrow strips running down the slopes, which were apparently related to cracks in the rock surface. *Pimelea gnidia* was growing here and there, usually isolated from other plants.

A steep, low scarp at about 3,000 ft. was covered with low-growing *Dacrydium biforme* and patches of *Hypolaena lateriflora.* At the base of this scarp, cushions of *Donatia novae-zelandiae* covered the rock; in crevices were *Cyathodes empetrifolia, Petriella thomsoni, Celmisia sessiliflora,* and *Prasophyllum colensoi.* (Fig. 7)

FLORA

When speaking of Mount Rochfort, which he describes as one of his favourite hunting grounds, Townson said ". . . but you look in vain for *Veronicas* with the exception of V. *buxifolia, Aciphyllas,* or any varieties of *Myosotis;* no *Raoulias* excepting *R. grandiflora,* and a few varieties of *Epilobium,* occur,"; he said also that Mount Frederick,

Fig. 7.—*Dacrydium biforme, Hypolaena lateriflora,* and *Gahnia* on the scarp at left. *H. lateriflora* with some *Danthonia rigida* var. *teretifolia* on slope to the right.

though a slightly higher mountain, was a poorer field for collecting than Mount Rochfort. Townson's remarks on the absence of such plants from Mount Rochfort apply equally well to the Burma Road locality. The area examined is floristically a poor one, and though examination of a wider area of the same type of country and at different seasons would probably add to the floristic list, it does not seem likely that the additions would be many. The country is low for the growth of alpine plants; bush, poorly developed, occurs only on the rocky sides of gullies, and is dominated for the most part by *Metrosideros umbellata,* which covers the ground with a dense layer of leaves in which little grows. The slopes of the western face, which are covered by dense bush, were not examined, being outside the area considered; there is no great variety of habitats. When these facts are taken into account the poverty of the flora is not so surprising.

Plants Absent from the Eastern Slopes of Mount Augustus

Species recorded by Townson, Petrie, or Cheeseman (1925) as growing only at elevations of 3,000 ft. and upwards on Mount Frederick or Mount Rochfort and which were not found on Mount Augustus between 2,000 and 3,000 ft. are:—

Cassinia vauvilliersii
Celmisia lateralis
C. parva
Coprosma serrulata
Epilobium linnaeoides
Gentiana montana
Ourisia macrocarpa
Raoulia eximia

Species recorded from the Papahaua Range or "coastal ranges" by Townson or by Oliver (1952) but not found on the Burma Road area, although from consideration of suitable altitude alone they might have been expected, are:

Abrotonella linearis
Anisotome haastii
Carex ternaria
Celmisia coriacea var. *cordatifolia*
C. dallii
Coprosma colensoi
C. linariifolia
C. parviflora
Cordyline indivisa
Dacrydium colensoi
Deyeuxia setifolia
Dianella intermedia
Dracophyllum pubescens
D. traversii
D. strictum
Gaultheria rupestris
Gentiana spenceri
Hebe buxifolia
Helichrysum bellidioides
Hierochloe fraseri
Hymenophyllum demissum
H. rufescens
Lycopodium fastigiatum
L. scariosum
L. volubile
Metrosideros parkinsoni
Microlaena avenacea
M. colensoi
Nothofagus menziesii
N. fusca
Olearia colensoi
O. arborescens
Ourisia macrophylla
Oxalis lactea (as *O. magellanica*)
Phormium tenax
Pimelea longifolia
Pseudowintera traversii
Pteris esculenta
Pterostylis venosa
Raoulia grandiflora
Senecio lautus
Schoenus pauciflorus
Todea superba
Townsonia deflexa
Trichomanes reniforme
Wahlenbergia saxicola

New Records

(a) Several plants not before specifically recorded for the coastal mountains between the Buller and the Mokihinui Rivers, were found:—

Astelia linearis var. *linearis* is one of the two most interesting new records. *A. linearis* was recorded by Townson as fairly plentiful on the mountains between 2,000 and 4,000 ft. However, this was before Skottsberg (1934) separated the variety *novae-zelandiae*—found in the North and South Islands—from Hooker's species—found on Stewart Island and the Auckland and Campbell Islands. The woolly covering on the under-surface of the leaves of the Bunna Road specimens is characteristic of *A. linearis* and similar to that on specimens collected by N. T. Moar in the Auckland Islands (Collection No. 1398). A specimen in the Botany Division Herbarium (No. 25407) collected by I. A. McNeur on 5 August 1952, from Denniston, over five miles to the southwest of Mount Augustus, is also *A. linearis* var. *linearis*.

Astelia subulata also has hitherto only been recorded from the Auckland and Campbell Islands and Stewart Island.

Other new records are:

Blechnum minus
Celmisia sessiliflora
Craspedophyllum armstrongii
Danthonia australis
Gaimardia ciliata—Recorded by Townson from Charleston only
G. setacea
Juncus antarcticus
Oreobolus pectinatus
Pittosporum crassicaule
Scirpus aucklandicus var. *subcucullatus*
S. aff. *merrillii*

(b) Two species of restricted known distribution found on Mount Augustus are:

Dracophyllum densum—A recently described species, hitherto known only from Mount Rochfort, Mount William, Denniston plateau, and Mount Davy in the Paparoa Range.

Danthonia rigida var. *teretifolia*—hitherto known only from Mount Rochfort, Mount William, Denniston plateau, and Fiordland.

(c) One specimen of a small creeping plant with small opposite leaves and without flowers or fruit, was found at about 2,500 ft. This bears considerable resemblance to *Tetrachondra hamiltonii*, but its leaves are a good deal larger than those of specimens in the Canterbury Museum. *T. hamiltonii* is recorded only from Southland and Otago.

(d) A few species recorded by Townson as occurring only below 2,000 ft. or on the coast, were found at 2,200 ft. or higher. These are:

Epacris alpina
—at 2,500 ft.

Gahnia rigida
—at about 2,000 ft.; only near coast according to Townson.

G. procera
-2,500 ft.

Gleichenia circinata var. *alpina*
-at 2,500 ft.; possibly but not certainly the *G. dicarpa* of Townson recorded up to 2,000 ft.

Leptopteris hymenophylloides
—at 2,500 ft.

Macroglena stricta
—at 2,200 ft.

Metrosideros umbellata
—up to about 3,000 ft. in gullies

Vauthiera australis
—at 2,500 ft.; only near the coast according to Townson.

Bryophytes and Lichens

A certain number of bryophytes and lichens (not an important part of the vegetation) were seen and collected but no attempt has been made to identify them.

Adventive Plants

No adventive plants were found—not even *Hypochaeris radicata*—except near the road edge and by the cookhouse of the open-cast coalmine. A few common weeds grow in soil and metal brought in for the construction of the road, and possibly in soil disturbed in road making. In no place are they found more than a few feet away from the wheel tracks, except where a small bridge crosses a sluggish creek. There, *Juncus effusus* and *J. macer* are growing some yards away from the road in muddy sand which has been unaffected by road making. Three indigenous plants, *Epilobium pedunculare*, *Raoulia glabra*, and *Acaena sanguisorbae* appear to have been introduced along with the adventive plants, in the course of road making. They are uncommon and confined to the road edge. Two or three years ago some grass seed was sown by the cookhouse, which stands near a gully at the open-cast mine. The following plants have become established by the building:

Lolium perenne
Holcus lanatus
Poa annua
Cynosurus cristatus
Agrostis sp.
Vulpia sp.
Juncus lampocarpus
J. bufonius
Trifolium repens.

According to the mine manager, the grass which is growing on a slope a short way below the cookhouse originated from seed which was washed down the gully with soil from the sown patch.

Catalogue of Plants

The following is a list of indigenous phanerogamic plants observed on and collected from the plateau. The numbers given are the authors'

collecting numbers. Specimens are in the herbarium of the Botany Division, Department of Scientific and Industrial Research, Christchurch.

Anisotome aromatica Hook. f.	1833
Aporostylis bifolia (Hook. f.) Rupp & Hatch	1848
Actinotus suffocata Rodway	1829, 2014
Archeria traversii Hook. f.	1866
Astelia cockaynei Cheesem.	1820
Astelia linearis Hook. f. var. *linearis*	1754
Astelia subulata (Hook. f.) Cheesem.	1888, 1988
Blechnum minus (R. Br.) Cockayne	1975
Carpha alpina R. Br.	1826
Celmisia dubia Cheesem.	1756, 1818, 1853, 1978, 2006
Celmisia graminifolia Hook. f.	1819
Celmisia laricifolia Hook. f.	2027
Celmisia sessiliflora Hook. f.	1774, 1864
Cladium teretifolium R. Br.	2015
Coprosma foetidissima J. R. & G. Forst.	2008
Coprosma aff. *C. retusae* Petrie	1765
Craspedophyllum armstrongii (Baker) Rae	1785
Cyathodes acerosa R. Br.	1761, 1824
Cyathodes empetrifolia Hook. f.	1854
Dacrydium biforme (Hook.) Pilger	1770, 1771, 1839
Dacrydium intermedium (Hook.) Pilger	1849, 1869, 1990, 2017
Danthonia australis Buchanan	1764
Danthonia gracilis Hook. f. var. *nigricans* (Petrie) Zotov	1815
Danthonia rigida Raoul var. *teretifolia* (Petrie) Zotov	1893, 2007
Donatia novae-zelandiae Hook. f.	1832
Dracophyllum sp.	1847, 1868
Dracophyllum densum Oliver	1962, 1996
Dracophyllum uniflorum Hook. f.	1762, 1827
Drapetes dieffenbachii Hook.	1816
Drosera spathulata Labill.	1831
Drosera stenopetala Hook. f.	1759
Elaeocarpus hookerianus Raoul	1834, 1846
Enargea parviflora (Kunth) Skottsb.	1870, 2020
Epacris alpina Hook. f.	1763
Epacris pauciflora A. Rich.	2004
Epilobium glabellum Forst. f.	2002
Epilobium pedunculare A. Cunn.	1980
Euphrasia wettsteiniana Du Rietz	1959
Exocarpus bidwillii Hook. f.	1838
Forstera mackayi Allan	1755, 1887, 1989, 2026
Gahnia procera Forst. f.	1892, 1977
Gahnia rigida T. Kirk	1971, 2025
Gaimardia ciliata Hook. f.	1767, 1835
Gaimardia setacea Hook. f.	1963
Gaultheria antipoda Forst. f.	2009
Gentiana townsoni Cheesem.	1814
Gleichenia circinata (Sw.) C. Christen. var. *alpina* (R. Br.) Hook. f.	1821
Grammitis billardieri Willd.	1773, 2021
Hebe sp. (not collected)	
Histiopteris incisa J. Smith	1976
Hypolaena lateriflora Benth.	1822
Juncus antarcticus Hook. f.	1981
Juncus effusus L.	1961, 1970
Leptopteris hymenophylloides Presl.	1757
Leptospermum scoparium Forst. (A low-growing form with horizontal branches)	1845, 2005
Leptospermum scoparium Forst. (An erect form)	2010
Libertia pulchella Spreng.	1994
Liparophyllum gunnii Hook. f.	1828
Luzula campestris DC	1973

Lycopodium ramulosum T. Kirk	1830
Macroglena stricta (Menzies) Copl.	2022
Mecodium rarum (R. Br.) Copl.	1775
Metrosideros umbellata Cav. Red flowered	1890
Metrosideros umbellata Yellow flowered	1958
Nertera depressa Banks et Sol. ex Gaertn.	2003
Nothofagus cliffortioides (Hook. f.) Oerst.	2018
Nothopanax colensoi Seem.	1884
Nothopanax simplex Seem.	1883
Oreobolus pectinatus Hook. f.	1879
Oreobolus pumilio R. Br.	1823
Pentachondra pumila (Forst. f.) R. Br.	1825
Petriella thomsoni (Petrie) Zotov	1766, 1855
Phormium colensoi Hook. f.	
Phyllocladus alpinus Hook. f.	1885
Pimelea gnidia Willd.	1758, 1769
Pittosporum crassicaule Cockayne in Laing et Gourlay	1844
Pittosporum sp.	1836
Podocarpus hallii T. Kirk	1993
Polystichum sp.	1995
Prasophyllum colensoi Hook. f.	1852, 2012
Pseudopanax lineare (Hook. f.) C. Koch	1837, 1867
Quintinia acutifolia T. Kirk	2019
Raoulia glabra Hook. f.	1968
Rapanaea divaricata (Hook. f.) Oliver	1882
Scirpus aucklandicus (Hook. f.) Boeck. var. *subcucullatus* (Berggr.) C. B. Clarke	1964, 1999, 2000
Scirpus aff. *S. merrillii* (Palla) Kükenthal	1965
Senecio bellidioides Hook. f.	1768, 1817, 1960
Senecio bennettii Simpson	1974
Tetrachondra sp.	1760
Thelymitra venosa R. Br. var. *cyanea* (Lindley) Hatch	1886, 2011
Uncinia sp.	1772
Utricularia monanthos Hook. f.	2024
Vauthiera australis A. Rich.	1972

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PRELIMINARY STUDIES IN THE CONTROL OF OESTRUS AND OVULATION IN ROMNEY EWES WITH PROGESTERONE AND PREGNANT-MARE SERUM

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Summary

A trial with 90 ewes at Ruakura in 1954 confirmed that frequent treatment with progesterone over 12 to 14 days in late anoestrus, followed by pregnant-mare serum, leads to oestrus and ovulation in a good proportion of treated ewes within 3 to 5 days of the last progesterone injection. P.M.S. injection at the start of oestrus did not affect normal ovulation and conception, but superovulation was delayed at least four days after oestrus.

Introduction

The general characteristics of the oestrous cycle in sheep and the mechanism of its hormonal control have received considerable attention which is admirably reviewed by Robinson (1951). Recent research into the role of progesterone, discussed by the same author (1954a, b) has established that the ovulation that can be induced in many anoestrous ewes by injection of pregnant-mare serum (P.M.S.) is more often accompanied by overt oestrus if progesterone is injected for some days prior to P.M.S. treatment.

Recently, too, by a chemical method of assay, the occurrence of a regular cycle in the progesterone concentration of ovarian blood during a normal oestrous cycle has been demonstrated by Edgar (1953, 1954).

It appears necessary that a reasonably steady level of progesterone be maintained during the greater part of the normal 16–17 day cycle, either from the corpus luteum of a preceding ovulation or by suitable injection treatment. The termination of this progesterone phase through either the waning of the corpus luteum or the cessation of injections, permits the development of the next follicle, the oestrogen from which should cause oestrus. Ovulation and luteinization then establish a new phase of progesterone control.

This progesterone-follicle stimulation-oestrogen-luteinizer sequence seems an adequate explanation for observed experimental results, and for the features and the common irregularities of the ewe's oestrous cycle.

Investigations carried out by Wallace (1954) and Wallace *et al.* (1954) into the possible field use of the gonadotrophic material of P.M.S. suggest that this superovulation technique has a place in the future on intensively-managed New Zealand fat-lamb farms, but that its use would be greatly simplified if the onset of oestrus in the late summer could be synchronized to within a few days, could be predicted accurately, and, ideally, could be hastened by some weeks. Such a measure of control would enable the whole flock to be treated with P.M.S. 2 to 5 days before oestrus without the tedious preliminary use of vasectomized rams and the consequent 2 to 3 weeks delay in lambing.

The response of ewes to hormones affecting the reproductive tract depends on breed, among other factors (Robinson 1951, Wallace 1954). The marked variation between breeds in the duration and intensity of anoestrus—particularly between Merino types and the common British breeds—makes it most desirable that the overseas work in the control and initiation of oestrus should be repeated under New Zealand conditions with Romney ewes.

Experimental

Material and Methods

Stock. A flock of 6½-year-old Romney ewes was available. The ewes chosen had normal oestrus and conception records, and had reared lambs successfully in 1953. The lambs were weaned on 24 December 1953 and the ewes were run on short dry pasture for several weeks thereafter to prepare them for tupping.

Progesterone. B.D.H. "Progestin" in ampoules of 25 mg in 1 ml. of oil was given intramuscularly.

Also 100-mg pellets of the same material were implanted on the side of the neck through a small incision, closed with one stitch, as a possible alternative to repeated injections.

Pregnant-mare serum. B.D.H. "Serogan" was given subcutaneously on the side of the brisket. Doses of 1,000 I.U. were used in Experiment 1 and of approximately 800 I.U. in Experiment 2.

Experiment 1—Induction of Synchronized Oestrus in Late Anoestrus

From previous work it was known that the first overt oestrous period of 60 to 70% of the ewes was likely to occur about the first week in March and treatment was therefore begun on 20 January 1954 in the hope of obtaining oestrus in early February, 3 to 4 weeks before the normal onset.

One group of 10 untreated ewes was slaughtered on 20 January to give information as to the probable ovarian state at that date of the ewes thereafter given progesterone, and another untreated group of 10 was slaughtered at the end of the progesterone period on 1 February for comparison of ovarian activity with those slaughtered earlier.

Four groups of 10 ewes were given progesterone, and a group of 30 untreated ewes kept to record the normal onset of oestrus. All groups were matched for body weight and condition.

The ewes were run as one flock with three fertile rams from 20 January onwards. The rams were raddled each morning and the colour changed every fourteen days. Each ewe in the four treated groups and the main control group was slaughtered 24-26 days after her first service, whether or not she returned to the ram in the interval.

Notes were made of the number, size, colour, etc., of follicles and corpora lutea, the number and position of embryos, degree of development and placentation, apparent viability, and any unusual or abnormal features.

The four courses of progesterone treatment are shown in Table 1.

TABLE 1. EXPERIMENTAL TREATMENTS
(No. of ewes in brackets)

Group and number of ewes	Date	Progesterone (mg) Jan. 20	23	26	29	Feb. 1	P.M.S (I.U.) Feb. 4
	Day of trial	1	4	7	10	13	16
1 (10)		(killed)	—	—	—	—	-
2 (10)		—	—	—	—	(killed)	-
3 (30)		—	—	—	—	—	-
4 (10)		100*	—	—	—	**	1000
5 (10)		75	—	—	50	—	1000
6 (10)		25	—	—	25	—	1000
7 (10)		25	25	25	25	25	1000

* pellet implanted ** pellet removed

Experiment 2—The Effect of P.M.S. Treatment at the Start of Oestrus

In Experiment 1, as in the earlier work which it was designed to confirm, gonadotrophic material was given three days after the last progesterone injection and oestrus followed within a rather short time, 1 to 3 days. Previous experiments at Ruakura (Wallace, 1954), since repeated on a larger scale (Wallace and Sinclair, unpublished) had shown that there was no great difference in response to P.M.S. whether administration was on the 12th, 13th, 14th, and 15th day of the cycle, i.e. 5, 4, 3, or 2 days, on average, before the following oestrus. It was interesting, however, to ascertain whether P.M.S. treatment could be delayed until oestrus was imminent, or had actually begun.

A flock of 60-odd ewes running with raddled Southdown rams was observed continuously for several periods of 3 to 4 days. Twenty-nine ewes whose oestrus periods coincided with the observation periods were used for this experiment. Twenty were treated with P.M.S. at the first signs of oestrus and nine left untreated. All were killed at various intervals after the first signs of heat, to record the course of follicular development and ovulation.

RESULTS

Experiment 1.

None of the ewes in Group 2 had been in oestrus before slaughter, so their ovulations must be considered as clear evidence of "silent" heat preceding the start of the breeding season proper. It is interesting to note at this point that this period of "silent" heats coincided with several overt oestrus periods in the main control group and was about 35 days (i.e. 2 cycles) before the rush of first tuppings of the thirty ewes in this latter group (Fig. 1). This suggests that some ewes have two ovulations, the first usually, and the second often, not accompanied by oestrus, prior to the effective start of the breeding season.

TABLE 2. OVARIAN STATE OF EWES KILLED, GROUPS 1 AND 2

Number of Ewes with	Ewes Killed on	
	Jan. 20	Feb. 1
1-cycle corpus luteum *and* recent ovulation	—	2
Functional corpus luteum *or* recent ovulation	1	5
Ripe follicles (> 4mm) but no ovulation	8	3
Inactive ovaries (no follicle > 3mm)	1	—

It is clear that, at the start of the progesterone injection period on 20 January, the experimental ewes had ripening follicles in their ovaries, but that their own oestrous rhythm had probably not at that stage been established by an ovulation.

Details of the individual animals are given in Table 6.

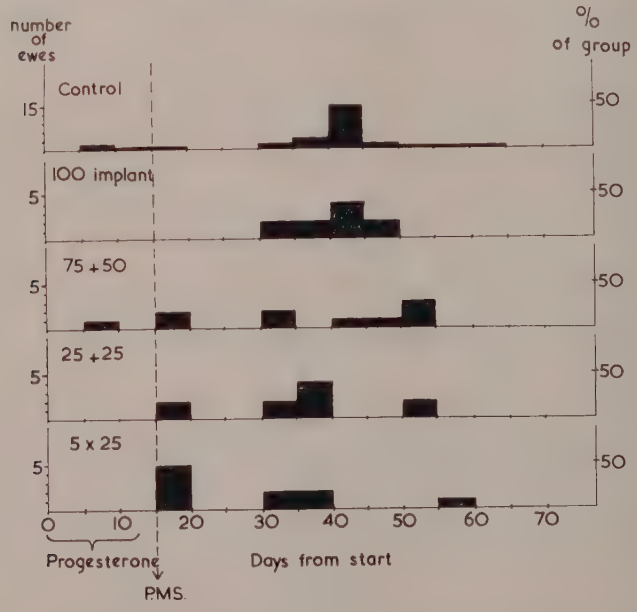

Fig. 1.—Number of ewes having first oestrus, in five-day periods.

Though only 10 ewes were used in each group, it is evident that all the treatments except the 100-mg. implantation modified the onset of oestrus. On reweighing the pellets after removal it was found that barely 15 mg had been absorbed from the 100-mg pellets implanted, which explained their ineffectiveness.

In the group receiving five 25-mg injections, five ewes came into oestrus on the day following P.M.S. treatment, i.e. the fourth day after the end of progesterone treatment. Only two ewes in each of the other

groups came on following P.M.S., but quite a number of ewes were served 15 to 20 days later. These latter ewes in all groups had old regressed corpora lutea in their ovaries, and presumably had ovulated without oestrus after their P.M.S. injection. Following on their progesterone conditioning, this ovulation apparently led to the initiation of a cycle of approximately normal length thereafter. Only one treated ewe was observed in oestrus during the progesterone period, but several ewes in the control group were tupped in this time. From Table 2 it appears that an odd ewe might have ovulated before the start of treatment on 20 January.

TABLE 3. CONCEPTION RESULTS

Number of Ewes which	Group				
	3 Control	4 100	5 75 + 50	6 25 + 25	7 5 x 25
Conceived at first oestrus	22	7	7	6	5
Missed, but returned to ram	2	1	3	2	4
Missed and did not return within 24 days	5	2	—	2	1
Either conceived or returned to the ram	24/29	8/10	10/10	8/10	9/10

It is possible that some ewes in the 3rd category of Table 3 may in fact have had a more recent ovulation but remained undetected by the ram, or might have returned to service later on, had they not been killed. Bearing in mind the limitations of the experiment, it does not appear that the progesterone–P.M.S. treatment impaired the likelihood of ultimate conception, though only five ewes held of the nine that came on immediately after the end of their treatments.

The ovulation-rate response to P.M.S. injection of the ewes that did not show oestrus until 15 to 20 days later has not been presented because of the uncertainty of counts of old corpora lutea. However, in the nine ewes that did show oestrus 1 to 3 days after P.M.S. administration and for which reliable counts could be made, ovulation rate varied from 1 to 15 with a mean of about 3, compared with about 1.1 for the control ewes, and for the subsequent ovulations of the P.M.S.-treated ewes.

When a ewe that had not conceived was not again marked by rams in the 25 days before her slaughter, a functional corpus at slaughter might equally be an unusually long-lived survivor from the heat 25 days before, or a fully developed corpus from a "silent" ovulation at the

normal interval i.e. 8 days earlier, at which the ewe had not been tupped. Of nine such cases, four were ewes from the control group, and one ewe in the unsuccessful implantation group had two very recently ovulated follicles when killed (ewe 122, Table 6). Most of these cases thus may have been true "silent" heats occurring after overt oestrus periods.

Experiment 2.

The data are shown in Tables 4 and 5.

TABLE 4. Control Group

No. of Ewe	Interval between Onset of Oestrus and Slaughter	No. and Condition of Corpora Lutea		No. of Follicles 4 mm. & larger		No. of Foetuses	
		L. Ovary	R. Ovary	L.	R.	L.	R.
98	24 hours	—	1 old	—	1	not known	
35	24 hours	1 very recent	1 old	—	—	,,	
81	60 hours	1 very recent	1 old	2	—	,,	
82	60 hours	1 very recent	—	—	1	,,	
4	72 hours	—	1 old 1 fresh	—	1	,,	
18	72 hours	—	1 fresh	—	3	,,	
86	25 days	—	1 normal	1	—	—	1
78	25 days	1 old	1 fresh	1	–		–
20	25 days	1 normal	—	1	—	1	—

In describing the corpora lutea the term *very recent* has been applied to cases where the ovulation point consisted of a raised highly vascular crater often with some loose luteal tissue forming within the cavity of the follicle—the term *fresh* to corpora still showing a definite point of rupture but consisting of less vascular, firmer luteal tissue—the term *normal* to solid well-coloured active corpora, and *old* to the pale, often creamy coloured, corpora from previous ovulations. Oestrus has been timed from the first tolerated attempt at mating.

The results can best be summarized by saying that in untreated ewes ovulations had occured within 24 hours of the start of oestrus and in treated ewes too a normal ovulation occurred at about this time. Marked follicular growth was evident in treated ewes slaughtered 48 to 84 hours after injection, and superovulation had occurred in one case by 96 hours, and in several more by six or seven days, after treatment at the start of oestrus.

TABLE 5. P.M.S.-TREATED GROUP
(Injected at early oestrus)

No. of Ewe	Interval between Onset of Oestrus and Slaughter	No. and Condition of Corpora Lutea		No. of Follicles 4 mm. & larger		No. of Foetuses	
		L. Ovary	R. Ovary	L.	R.	L.	R.
33	15 hours	1 just ovulating	1 old	—	—	not known	
31	48 hours	—	1 old 1 very fresh	5	1	not known	
45	84 hours	—	1 fresh	5	11	not known	
92	84 hours	—	1 fresh	4	4	not known	
23	6 days	1 normal	2 very recent	—	2	1 (washed out)	
96	7 days	1 normal	3 very recent	—	—	not known	
30	25 days	1 normal	—	1	—	1	—
80	25 days	1 normal	—	—	3	1	—
17	25 days	1 lut. foll.	1 normal	—	3	—	1
84	25 days	1 lut. foll.	1 normal	—	—	—	1
32	25 days	—	3 normal	—	—	—	1
8	25 days	—	3 normal	2	1	—	1
11	25 days	—	1 normal 1 older	1	—	—	—
88	25 days	1 normal	—	—	1	1	—
43	25 days	1 normal	—	—	—	1	—
13	25 days	1 normal 1 lut. foll.	—	1	1	1	—
7	25 days	1 normal 1 older	—	1	—	—	—
21	4 days	1 follicle freshly ruptured	1 fresh	5	7	not known	
83	4 days	—	1 fresh	2	6	not known	
87	4 days	1 fresh	—	8	5	not known	

It appeared that P.M.S. given subcutaneously at this time did not affect the normal ovulation and conception, but that superovulation was delayed until at least four days after oestrus.

These results were confirmed by data from a further thirty ewes that were allowed to lamb after 15 had been injected with P.M.S. at the start of oestrus. There was no difference between treated and untreated ewes in the occurrence of multiple births nor in the number of ewes that failed to hold to service.

TABLE 6. CONCEPTION AND OVULATION DATA, EXP. 1

	Ewe Tag No.	First Oestrus			Second Oestrus		Comments
		Days from Start	No. of Ovulations	No. of Foetuses	Day and Interval	No. of Ovulations	
Group 3	226	29	1	0	32 (23)	1	
	281	10	1	0	—	—	No record of 2nd oestrus
	162	11	1	1	—	—	
	280	20	1	1	—	—	
	20	32	1	1	—	—	
	300	33	1	1	—	—	
	272	38	1	1	—	—	
	268	39	1	1	—	—	
	153	39	1	0	—	—	No record of 2nd oestrus
	15	40	1	1	—	—	
	218	40	1	1	—	—	
	213	41	2	0	59 (18)	2	
	155	41	2	2	—	—	
	78	41	1	1	—	—	
	130	42	1	1	—	—	
	57	42	1	1	—	—	
	231	43	1	2	—	—	Apparently monozygotic
	4	43	1	1	—	—	
	62	44	1	1	—	—	
	76	44	2	1	56 (12)	—	Probably a spurious tupping mark
	104	44	1	1	—	—	
	172	44	1	1	—		
	330	44	1	1	—	—	
	248	45	2	0	—	—	No record of 2nd oestrus
	216	47	1	0	—	—	No record of 2nd oestrus
	8	49	1	1	—	—	
	6	53	1	1	—	—	
	56	56	1	1	—	—	
	42	63	1	1	—	—	
Group 4	160	32	1	0	49 (17)	1	
	72	33	1	1	—	—	
	383	36	1	0	53 (17)	1	
	222	40	1	0	56 (16)	1	
	385	41	1	1	—	—	
	94	42	?	0	60 (18)	1 (?)	One ovary lost at slaughter
	149	43	2	2	—	—	
	180	47	1	1	—	—	
	120	48	1	1	—	—	
	122	59	1	0	?	2	No record of 2nd oestrus but had two very recent ovulations
Group 5	123	6	1	1	—	—	Chance?
	64	18	1	0	35 (17)	1	
	275	19	15	5	—	—	7 more foetuses being resorbed
	112	33	1	1	—	—	
	255	34	1	1	—	—	
	167	41	2	0	—	—	No record of 2nd oestrus
	386	47	1	0	58 (11)	1	
	184	51	1	1	—	—	Also a luteinized follicle
	92	55	2	0	—	—	No record of 2nd oestrus
	232	55	1	1	—	—	

Group 6	206	18	1	0	34 (16)	1	
	150	19	2	1	—	—	
	251	33	1	1	—	—	
	14	34	1	1	—	—	
	82	38	1	1	—	—	
	237	38	1	0	55 (17)	—	Two luteinized follicles
	137	40	1	1	-	—	
	208	40	1	0	58 (18)	1	
	19	54	1	1	-	—	
	260	55	1	1	- -	—	
Group 7	2	17	3	0	—	—	No record of 2nd oestrus
	5	17	1	1	—	—	
	51	17	1	1	—	--	
	250	17	4	3	—	—	
	258	18	1	0	—	—	No record of 2nd oestrus
	244	32	1	1	—	-	
	79	33	1	1	—	—	
	196	36	1	0	53 (17)	1	
	285	40	1	1	—	—	
	189	58	1	0	—	—	No record of 2nd oestrus

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THE RELATIONSHIP OF NECTAR SECRETION (VOLUME) AND SUGAR CONCENTRATION TO INSECT POLLINATION OF PLUMS (*Prunus* spp)

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Summary

Field trials were carried out in Auckland during the plum blossoming periods 1951–52–53–54 in an attempt to establish factors responsible for the unreliable cropping of Billington and Purple King plums (*Prunus salicina*).

Variations in nectar, yield, and sugar concentration throughout the blossom periods, the influence of these and other factors on visitation of pollinating insects, and the comparative attraction to insects of plum and other plants flowering at the same time were studied.

Honey bees (*Apis mellifera*) were found to constitute 98.53% of all observed insect visitors to plum.

Attraction of bees to plum blossom is evident only during periods of favourable weather and is directly related to proximity of hives.

As unsettled weather is usually experienced during plum blossoming, colonies of bees, required for pollination purposes, should be sited within a radius of not more than 150 yards.

Plum pollen is not sufficiently attractive to pollen-gathering insects to ensure effective pollination.

Sources of nectar likely to be more attractive to bees than plum blossom should be reduced to a minimum.

INTRODUCTION

The primary purpose of the investigation was to establish factors responsible for poor cropping of Purple King and Billington plum varieties in the Auckland district.

Work in the 1951 season covered orchards at Oratia, Henderson, Birkdale, Northcote, and Albany. Comparisons were made of the influence of varying managements, aspect of land, cultural treatment, and soil types.

Purple King and Billington were the main subjects of investigation, but varieties Wilsons Early, George Wilson, Sultan, Vailes Early, Sharps Early, Santa Rosa, Evans Early, Alpha, Elephant Heart (syn. Masterpiece) and South Australian Cherry (Myrobalan) were also observed for purposes of comparison. Cultural treatment was similar throughout and followed the usual practice of stone-fruit growers. Aspect varied, but shelter provision was adequate in all cases. Soil types varied in each instance, being as under:—

Oratia —Clay podzol. Little or no topsoil.

Henderson —Brown loam overlying clay subsoil.

Birkdale —Brown granular clay loam overlying heavy clay subsoil.

Northcote —Secondary clay podzol (gum soil) overlying heavy clay subsoil.

Albany —Granular clay loam overlying heavy clay subsoil.

As variations of aspect, soil type, and timing and application of cultural treatment, between the five orchards, were found to have no significant bearing on nectar secretion and its sugar concentration in 1951, the observations were confined to the Northcote and Albany orchards in 1952, and to the Albany orchard alone in 1953 and 1954.

In the course of the early part of the investigations, emphasis was placed on the importance of the attraction afforded by Purple King, Billington, and other plum varieties to pollinating insects. This was regarded as one of the major factors to be considered, as insect transfer of pollen is of fundamental importance in most forms of stone-fruit production. The information in this article is therefore based on insect activity and its relation to factors of weather, nectar secretion, and sugar concentration. Observations cover four seasons, 1951–54.

EXPERIMENTAL METHODS

No previous work appears to have been done in New Zealand on the sugar concentration of fruit-blossom nectar and its relation to fruit set. Procedure was therefore based on methods used by Vansell,[1] in his experimental work on the usefulness of honey bees in pollination, carried out at orchards near Camino, California, in the fruit blossoming season of the years 1931–32–33.

Sugar concentrations were determined by Bellingham and Stanley pocket-type sugar refractometers; two were used, having ranges of 0% to 50% and 40% to 80% sugar respectively. These instruments indicate only the percentage of total sugars present. The relative proportions of sucrose and other sugars was not considered important in the present investigation. These instruments are standardized to read accurately at 68°F. Maintenance of samples at a constant temperature was not practicable, and in any case temperature variations throughout observations were not sufficient to cause any significant degree of error, so that corrections were not made.

Sugar concentration readings from blossom were taken by carefully removing the petals, stamens, and style, and applying the nectar directly to the refractometer prism. At least six readings were taken at each check of individual trees and averaged. Blossoms for these readings were taken from high and low limbs and the shaded and sunny sides of the trees. Up to 10 blossoms were needed at times to provide sufficient nectar to give one reading. Readings from the contents of honey sacs of honey bees were obtained from bees working blossom for nectar and from returning field bees at the hive entrance. Specimens were captured and killed with chloroform and dissected, and the contents of the honey sac were placed on the refractometer prism. During periods of plentiful nectar supply it was not necessary to destroy bees for this purpose, as it was found that, by holding the insect lightly between the thumb and forefinger and exerting a slight pressure on the abdomen where it joins the thorax, nectar would be regurgitated immediately and could be placed directly on the prism. The number of samples taken from bees on blossom was governed by the number of bees present at the time, and ranged from 4 to 30 at each check. Checks at the hives were from 40 bees on all occasions. Whenever possible, checks were taken at

30-minute intervals. Sugar concentration readings of the nectars of competitive sources were all taken from the honey sacs of bees working the blossoms of these plants.

The volume of nectar secreted was visually estimated on the following arbitrary scale: Heavy: Moderate: Slight: Very Slight: Nil. Recordings made on different plum varieties were related to blossom size and capacity of nectaries. A recording showing heavy secretion by Purple King, which has a larger blossom than most, indicates a greater total secretion per individual bloom, than does a heavy recording from Billington. All recordings are relative to the capacity of the variety named.

Counts of visiting insects to plum were made visually, at timed intervals, co-incidentally with recordings of sugar concentration of blossom.

Air temperature and relative humidity were recorded half-hourly on a Zeal wet and dry bulb hygrometer. Soil temperatures were recorded half-hourly at two points in each orchard to a depth of 14 in.

Lacking an anemometer, wind strength at the orchard was estimated on the Beaufort scale. Light intensity and cloud density were recorded on an arbitrary basis of: Heavy overcast: Overcast: Light overcast: Cloudy: Occasional cloud: Clear.

The distribution of beehives in and adjacent to the orchards varied widely. At Albany and Northcote sufficient healthy vigorous colonies of bees to meet the estimated maximum pollination requirements were placed at distances of 25–150 yd. from observed varieties. The orchards at Henderson, Oratia, and Birkdale were not provided with additional bees. In each case the nearest known hives were 500 yd. or more distant.

Results and Discussion

The classification of insect visitors into groups was as follows: honey bees, syrphid flies, solitary bees (Andrenids), bumble bees, all others. Throughout the experiment honey bees were by far the most frequent visitors, forming 98.53% of the observed total; syrphid flies were next in order of importance, forming 0.91% of the total. Others formed but 0.56% of the total (Table 1). While the weather conditions around the blossoming period of plum do not greatly favour the develop-

TABLE 1. Insect Visitors Observed on Plum Blossom at Auckland, 1951–54

Insects	Number	Percentage of Total
Honey bees	23,678	98.53
Syrphid flies	220	0.91
Solitary bees (Andrenids)	10	0.04
Bumble bees	33	0.13
Others	90	0.37

ment of insects other than honey bees, the extremely low incidence of these other insects was notable in view of the favourable circumstances provided by the surrounding country for the proliferation of insect life.

The diurnal activities of honey bees and other insects on plum is illustrated by the data of Table 2. This and Table 1 illustrate the relative importance of honey bees to the pollination of plums. Apart

TABLE 2. INSECT VISITORS TO PURPLE KING PLUM BLOSSOM AT 15-MINUTE PERIODS ON 16 SEPTEMBER 1953

Time of Observation	Honey Bees	Syrphid Flies	Solitary Bees (Andrenids)	Bumble Bees	Others
8.45 — 9 a.m.	—	—	—	—	—
9 — 9.15	—	—	—	—	—
9.15 — 9.30	—	—	—	—	—
9.30 — 9.45	—	—	—	—	—
9.45 — 10	—	—	—	—	—
10 — 10.15	—	—	—	—	—
10.15 — 10.30	—	—	—	—	—
10.30 — 10.45	—	—	—	—	—
10.45 — 11	—	—	—	—	—
11 — 11.15	—	—	—	—	—
11.15 — 11.30	—	—	—	—	—
11.30 — 11.45	2	—	—	—	—
11.45 — Noon	10	—	—	—	—
1 p.m.— 1.15	20	—	—	—	—
1.15 — 1.30	20	—	—	—	—
1.30 — 2 p.m.	15	—	—	—	—
2 — 2.15	15	—	—	—	—
2.15 — 2.30	20	—	—	—	—
2.30 — 2.45	8	—	—	—	—
2.45 — 3	4	—	—	—	—
3 — 3.15	20	—	—	—	—
3.15 — 3.30	15	—	—	1	—
3.30 — 3.45	10	—	—	—	1
3.45 — 4	—	—	—	—	—
4 — 4.15	—	—	—	—	—
4.15 — 4.30	—	—	—	—	—
	159	—	—	1	1
	98.75	—	—	0.625	0.625

Weather cloudy and cool in early morning. Air Temperature rose from 53°F. to 63°F.

Cloud dispersed at midday. Humidity fell from 87% to 54%. Plum at 90% to 100% full bloom.

from the high preponderances of honey bees over all other insects observed as visitors to plum blossom, their activity in securing nectar and pollen is much more effective in the distribution of pollen than is that of others. Syrphid flies are possibly good agents for the distribution of pollen, as they feed upon it and move vigorously across the blossoms when doing so; but their body structure does not favour the transference of pollen to the same extent as does that of the more specialized honey bees.

The attraction of plum blossom to honey bees is dependent upon several factors, viz., proximity of hives, volume of nectar secretion, sugar concentration of nectar, weather conditions during the flowering

period, and the occurrence and influence of other sources of nectar. Discussion on the subject of bee attraction of plum must therefore involve all of these factors. To relate bee visits to one particular factor, e.g., weather conditions, would only be possible by assuming all other conditions to be favourable. The effect of proximity of hives on honey bee visits to observed plum trees is illustrated by Table 3. During the

TABLE 3. Influence of Hive Distance on Bee Visits: A (Albany) 25-50 yd. B (Birkdale) 500 yd. C (Northcote) 25-50 yd.

Date	Time of Day	A		B		C	
		Variety*	Bee Count per Tree	Variety*	Bee Count per Tree	Variety*	Bee Count per Tree
30 Aug.	10.30 — 3	B'ton	10 — 25	B'ton	Nil		
4 Sept.	10 — 3	„	6 — 80	„	3 — 10	B'ton	3 — 36
10 „	10 — Noon			„	Nil	„	Nil
11 „	11 — 2.15	„	3 — 20			P. King	6 — 30
17 „	9.30 — 4					„	4 — 100
20 „	9.45 — 2.30			P. King	3 — 30		
21 „	9.30 — 2	P. King	5 — 30			„	50 — 75
25 „	11 — 3			„	Nil — 3		
26 „	11 — 2	„	5 — 40				
28 „	10 — Noon			„	1 — 20		
28 „	1 — 3	„	3 — 75				

* B'ton = Billington. P. King = Purple King.

period shown in this table, conditions influencing bee flight other than proximity were comparable in all orchards. Weather was essentially similar throughout the time recorded. The period was the driest experienced at this time of the year since meteorological records were initiated in Auckland, with skies generally over-cast throughout and little wind. Observations in subsequent years gave comparable results where the weather conditions at the time and points of observation were essentially similar to one another. The number of honey bee visits to plum blossom is always related to the prevailing conditions of air temperature, humidity, wind strength, and light intensity, and all these factors must be favourable to provide optimum conditions for bee flight. Fig. 1 and Table 4 illustrate the combined effect of these factors. In early spring when plums blossom, weather conditions are usually extremely changeable and all varieties are liable to frequent interruption of insect visits. This is particularly serious in the case of wholly or partly self-sterile varieties. To ensure maximum pollination service from honey bees it is necessary that only strong colonies be used and that they be located not more than 150 yd. from the trees to be serviced.

Nectar secretion was studied on all observed varieties of plum. The maximum yield varied with variety. Purple King producing the

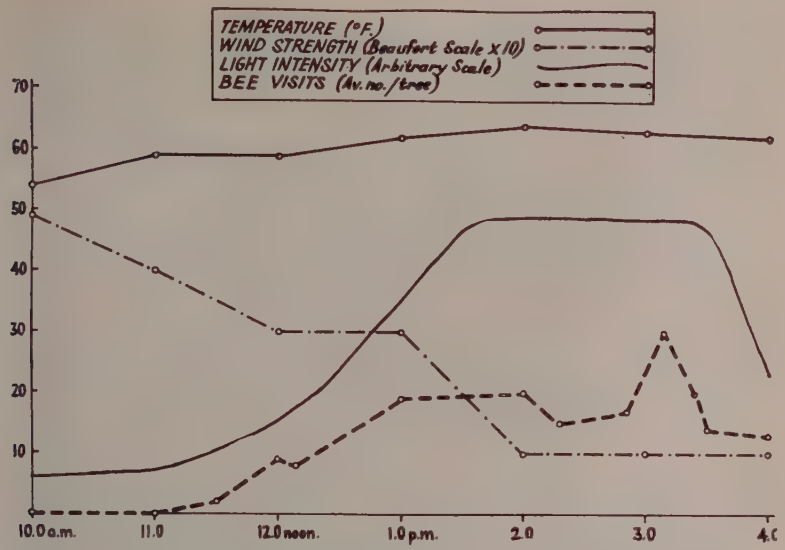

Fig. 1.—Bee activity in relation to diurnal variations in air temperature, light intensity, and wind strength. Purple King, full bloom, 17 September 1953.

TABLE 4. BEE ACTIVITY IN RELATION TO AIR TEMPERATURE, RELATIVE HUMIDITY, CLOUD, AND WIND STRENGTH

(Albany, Auckland, 17 Sept 1953)

Time	Honey Bees		Air Temperature °F.		Ref. Humidity %		Wind*	Cloud
	Av. No.	No. of Counts	Av.	Obs.	Av.	Obs.		
9 — 9.30	—	5	53.5	3	87	3	3	Light cloud
9.30 — 10	—	5	55.8	4	83.2	5	4	O'cast
10 — 10.30	—	2	55	2	85	2	2	O'cast
10.30 — 11	—	3	56.3	3	76.6	3	3	Light o'cast
11 — 11.30	—	3	56	3	76.5	3	3	Heavy o'cast
11.30 — 12	4.8	6	58.1	7	73.4	7	3	Light o'cast
1 — 1.30	15	5	62	4	68	4	3	Occ. cloud
1.30 — 2	15	6	64	2	64	2	1	Light cloud
2 — 2.30	15	3	64	2	60	2	1	Clear
2.30 — 3	9	3	63	3	55	3	1	Clear
3 — 3.30	19.5	4	62.7	4	54.8	5	1	Clear
3.30 — 4	17.5	3	62	2	54	3	1	Clear
4 — 4.30	2	3	59	2	54	2	0	Clear
4.30 — 5	—	2	58	1	55	2	0	Clear

* On Beaufort Scale.

greatest volume per bloom at any given stage. Sultan also yielded prolifically. Other varieties produced lesser amounts with the exception of Elephant Heart (syn. Masterpiece) where no observable quantity was found at any time. The volume of nectar secreted was closely related to the degree of relative humidity and air temperature. The volume was always greatest in the mornings when the relative humidity was comparatively high. Volume rapidly declined with rising temperatures and falling relative humidity. Relative humidity was found to be much more closely related than air temperature, a decline of 5% in this factor resulting in a much greater diminution of nectar secretion than a comparable rise in air temperature (Fig. 2). Soil temperature

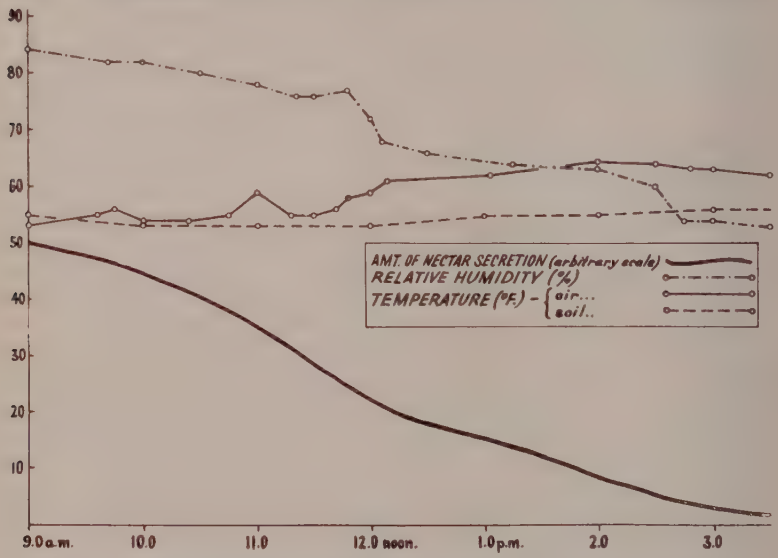

Fig. 2.—Amount of nectar secretion in relation to diurnal variations in relative humidity and air and soil temperatures. Purple King, full bloom, 17 September 1953.

within the range experienced throughout the trial has no apparent effect on either the volume secreted or its sugar concentration. The quantity of nectar secreted by individual blossoms at the same stage of development was similar on any part of one tree. The greatest overall volume was always produced within the stage of blossom development 75% bloom 25% petal fall, with the maximum always evident during periods of rising temperatures, high relative humidity, and little wind. Tree vigour had no observable effects on nectar secretion. Nectar secretion was usually greatest in the early morning period but tended to diminish and dry out rapidly with falling humidity and increasing temperatures as the day progressed. It frequently disappeared entirely by early afternoon. Under comparable weather conditions visits of nectar-gathering insects were always most frequent at periods of maximum nectar secretion (Fig. 3).

Sugar concentrations of plum nectar varied from 1% to 36%, all varieties giving similar readings under comparable conditions. Average readings, taken direct from blossoms, ranged from 1% to 25%. Readings

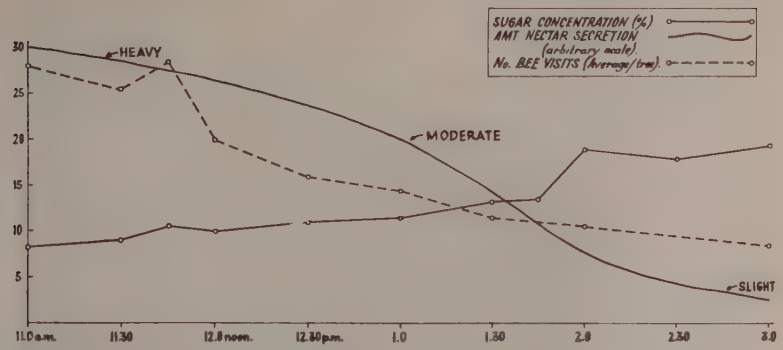

Fig. 3.—Diurnal variations in sugar concentration and amount of nectar secretion in relation to number of bee visits. Purple King, full bloom, 16 September 1952.

taken from the honey sacs of bees working plum blossom gave averages 4% to 5% higher than readings taken direct from plum blossom at the same time (Table 5). Throughout the whole trial this variation remained constant. Similar variations were found by Vansell in his work at Camino, California.

TABLE 5. SUGAR CONCENTRATION OF PLUM NECTAR (PURPLE KING) FROM BLOSSOM AND FROM HONEY SACS

(Auckland, 18 Sept. 1953. 95% to 100% full bloom)

Time	Nectar from Blossoms		Nectar from Honey Sacs		Amount of Nectar Secretion
	No. of Samples	Av. Sugar Conc. %	No. of Samples	Av. Sugar Conc. %	
9 — 10	48	17.5	6	23.1	V. Slight — Moderate
10 — 11	30	18.7	21	24	V. Slight — Slight
11 — 12 noon	48	21.5	24	25.8	Nil — V. Slight
2 — 3	23	23.5	15	29.2	Nil — V. Slight
3 — 4	Nil		Nil		Nil

A clear bright day. Slight breeze. Air Temperature rising from 54°F. to 61°F. Humidity falling from 64% to 53%.

Sugar concentration in all varieties of plum was found to be inversely proportional to the volume of nectar being secreted. At periods of maximum nectar secretion sugar concentration was always low, but it rose as volume declined. Although varieties differed considerably in the maximum volume of nectar secreted, the percentage of sugar present was similar in all varieties at similar times.

Although honey bees usually favour nectars of high sugar concentration over those of relatively low sugar content, it was found in the course of this trial that bee attraction to plum blossom was generally greatest at periods of maximum nectar secretion and correspondingly

low sugar concentration, rather than at times when sugar concentration was relatively high and nectar volume much less (Fig 2). The average sugar concentration of plum nectar at periods of maximum nectar yield was often less than 10%. Nectars of very low sugar content are not likely to be gathered by bees for conversion to honey. It is thought that bees utilize these very dilute secretions in place of the normal water supply. It was not possible to determine conclusively if this was so, but it was noted that the bees' usual sources of water were abandoned when voluminous nectar supplies of low sugar content were present.

The nectars from different species of plants vary widely in sugar content. Manuka (*Leptospermum scoparium* Forst.), wild turnip (*Brassica campestris* L.), *Hakea saligna* Knight, and kowhai (*Sophora microphylla* Ait.) were, in the localities observed, the principal competing plants. All produce nectar of far higher average sugar concentration than plum, and afford much greater attraction to nectar-gathering insects.

At all orchards observed, the plum was subject to competition from stands of plants yielding nectars having sugar concentrations up to 300% greater than plum. When weather conditions were suitable for bee flight, the influence of these plants was such that bees were found to desert observed plum trees entirely in favour of these competitors. Because of the considerable area of plum present at each point of observation, only those plants present in sufficient numbers to provide effective competition were considered. At each point these were found to be, in order of importance, manuka, wild turnip, *Hakea saligna* (used as shelter hedges), and kowhai. Table 6 shows the range and average sugar concentration of the nectar of these plants as compared with

TABLE 6. SUGAR CONCENTRATIONS OF NECTARS FROM HONEY SACS OF BEES WORKING PLUM AND COMPETITIVE SOURCES

(Auckland, 1953)

Date	Plum		Manuka		*Hakea saligna*		Brassica		R.H. %
	Range	Av.	Range	Av.	Range	Av.	Range	Av.	
Sept. 9	—	—	50—68	65	35—49	40	—	—	79—74
10	—	—	38—51	40	28—40	33	—	—	89—79
11	—	—	42—57	50	25—40	35	—	—	88—74
12	—	—	38—49	43	22—34	25	—	—	79—75
14	25—29	27.6	47—68	60	38—45	42	—	—	71—58
15	—	—	50—63	59	—	—	—	—	82—71
16	10—12	10.3	42—44	36	—	—	—	—	88—87
17	17—36	26.5	38—65	55	22—36	30	35—45	40	88—54
18	20—38	30.1	44—66	55.5	35—44	40	30—46	42	64—58
19	23—26	24.5	55—66	60	—	—	—	—	71—58
21	13—34	25	51—66	58	—	—	38—44	40	82—55
22	16—27	21.6	47—64	56	—	—	36—46	40	79—69

plum. Readings were taken from the above species at similar times. Table 7 shows the approximate estimated percentages of the populations of the installed hives at the orchards which continued to frequent plum when other nectar sources were available. The percentage figures in this table are based on the assumption that all sugar concentration

TABLE 7. SUGAR CONCENTRATIONS FROM HONEY SACS OF BEES ON PLUM BLOSSOM AND AT HIVE ENTRANCE SHOWING PERCENTAGE OF BEES WORKING COMPETITIVE SOURCES

(Auckland, September 1953)

Date	Time	Av. Conc. at Tree	Av. Conc. at Hive	Av. Conc. of Outside Sources	Approx. Percentage Favouring	
					Plum	Competitive Sources
Sept. 16	A.M.	10.3	28.3	36	—	100
17	A.M.	18.3	27.2	30—40	17.5	82.5
17	P.M.	30.1	45.8	45—60	17.5	82.5
18	A.M.	28.7	47.9	40—49	37.5	62.5
18	P.M.	31.5	45.8	42—62	25	75
19	A.M.	24.5	51.9	60	5	95
21	A.M.	21.6	46.25	40—55	7.5	92.5
21	P.M.	29.5	48.6	62	10	90
22	A.M.	—	37.4	40—50	—	100
22	P.M.	21.6	43.6	40—62	22	78

readings found to be within 5% of the average given by plum at the time were from that source. Bees were not found in any significant numbers on plants other than those specified in the table. Consequently the approximations should be reasonably accurate. These tables emphasize the importance of the provision of a plentiful supply of honey bees if insect pollination of plum is desired. Cover crops and heavy growth of weeds likely to bloom coincidentally with plum should be controlled by mowing to eliminate competition. Where control of adjacent competitive trees and plants outside the orchardist's boundary is not possible, the installation of a greater number of hives than is normally required will tend to ensure a better pollination service.

Pollen-gathering habits of honey bees were observed continuously throughout the course of the trial. In the 1951 season, bees were not seen to gather plum pollen until 17 September when a few were observed on Purple King, then at full bloom. During this season, adequate pollen supplies were secured by the bees of observed hives at all times, the main sources being gorse (*Ulex europaeus*), wattle (*Acacia* spp.), and Brassicae. From 17 to 28 September when observations for 1951 concluded, pollen gatherers appeared in increasing numbers but did not at any time form more than 10% of the observed total of bees. In the subsequent seasons 1952-54 pollen-gathering bees were in evidence on plum at various times throughout the whole period of observation.

Pollen gatherers were not usually present throughout the whole day but seemed to favour periods when nectar was absent or in very limited supply.

Observations with a view to determining the pollens most favoured by honey bees were made at the Albany orchard. Hives were fitted with pollen traps and counts made of the takings. A 300 × field microscope was used for pollen identification. For the purposes of the trial, pollens were placed in two groups : plum, and all others. Plum pollen is not favoured by honey bees when other sources are readily available. Pollen-gathering bees were frequently seen to desert plum pollen in favour of that from competing plants. Plum pollen is not sufficiently attractive to bees to offset the counter attraction to nectar-gathering bees of other flowers with a greater nectar flow. The activities of pollen gatherers on the blossom are, however, considered to be much more effective in the distribution of pollen than are those of honey gatherers.

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ADVENTITIOUS ROOT-SHOOTS OF *Dacrydium colensoi* Hook. IN WESTLAND, SOUTH ISLAND, NEW ZEALAND

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(Received for publication, 28 June 1955)

Summary

Accessory adventitious shoots arising from lateral roots of *Dacrydium colensoi* Hook. (silver pine) in swampy areas in Westland are reported. The first leaves of such shoots are similar to adult leaves and these are succeeded by intermediate and then by juvenile leaf forms which gradually undergo transition to adult leaves. The fact that *D. colensoi* is principally a dioecious species assists in deciding whether "individuals" in clumps with tangled root systems are either adventitious root-shoots or plants that have grown from seed. The ecological and practical significance of such shoots is briefly discussed.

Introduction

Reports from Westland that root "suckers" occur in *Dacrydium colensoi* Hook. (silver pine) were checked during a field examination of this species growing in swampy sites in Westland. These examinations confirmed the reports. As there is no published record, or description, of the occurrence of such shoots in *D. colensoi,* it is the purpose of this paper first to provide a record and description and, second, to discuss briefly their ecological significance.

The areas examined were located between Hokitika and Bruce Bay, about 120 miles south of Hokitika. Particular attention was paid to areas at Kokatahi, at the Rimu State Forest near Rimu, and at Hari Hari (Fig. 1). Of these, the first two have been altered greatly by logging and burning; the third has never been logged or burnt as far as is known.

Adventitious Root-shoots

The lateral roots of *Dacrydium colensoi* are sometimes of great length and frequently run close to the soil surface or along the surface with the upper side of the root exposed. These roots branch frequently, so that there is a dense tangle of roots where many plants grow together. A shallow root system is characteristic of trees growing in swampy sites, but in *Dacrydium colensoi* there is one feature of the root pattern to which attention should be drawn. Where the permanent water-table level is some inches below the soil surface, the root grows down to this level and then loops to the surface to grow once again in the horizontal plane. This phenomenon is repeated at irregular intervals. An apparently similar "characteristic undulation" of lateral roots has been described for *Pinus contorta* growing in sphagnum bogs near Seattle, U.S.A. (Rigg and Harrar, 1931).

The adventitious shoots develop from buds which appear singly or in clusters on the long lateral roots and although these buds are most frequent on the upper surface of the root they are not restricted to this position. The bud grows through the outer tissues of the root, which in

Fig. 1.—Location of the areas investigated in detail and mentioned in text.

consequence form a collar around the base of the bud. A protective cap of cortical tissue is present for a short time (Fig. 2).

Adventitious shoots are produced on all surfaces of the lateral root and those that spring from the under surface of the root soon begin to grow upwards towards the light (Fig. 3).

Adventitious shoots may grow closely together (Fig. 3) and in disturbed areas in the Rimu State Forest there are dense clumps of *Dacrydium colensoi* and their general appearance and dense growth suggest that the seeming individuals in each clump have originated from one plant, and that all or most of them may be adventitious in origin. The root systems of such clumps are so tangled that they could not easily be traced, and in order to investigate the origin of the stems in each clump the type of cone produced on each individual in each of two clumps was determined. This was possible as *D. colensoi* is a dioecious species.*

In one clump every stem, with the exception of a few on which no flowers were found at all, was female; in the other, every stem, with the same exception, was male. These observations afford grounds for assuming that these and similar clumps have originated as adventitious shoots from one lateral root.

*Monoecious specimens have been seen, but these are comparatively rare.

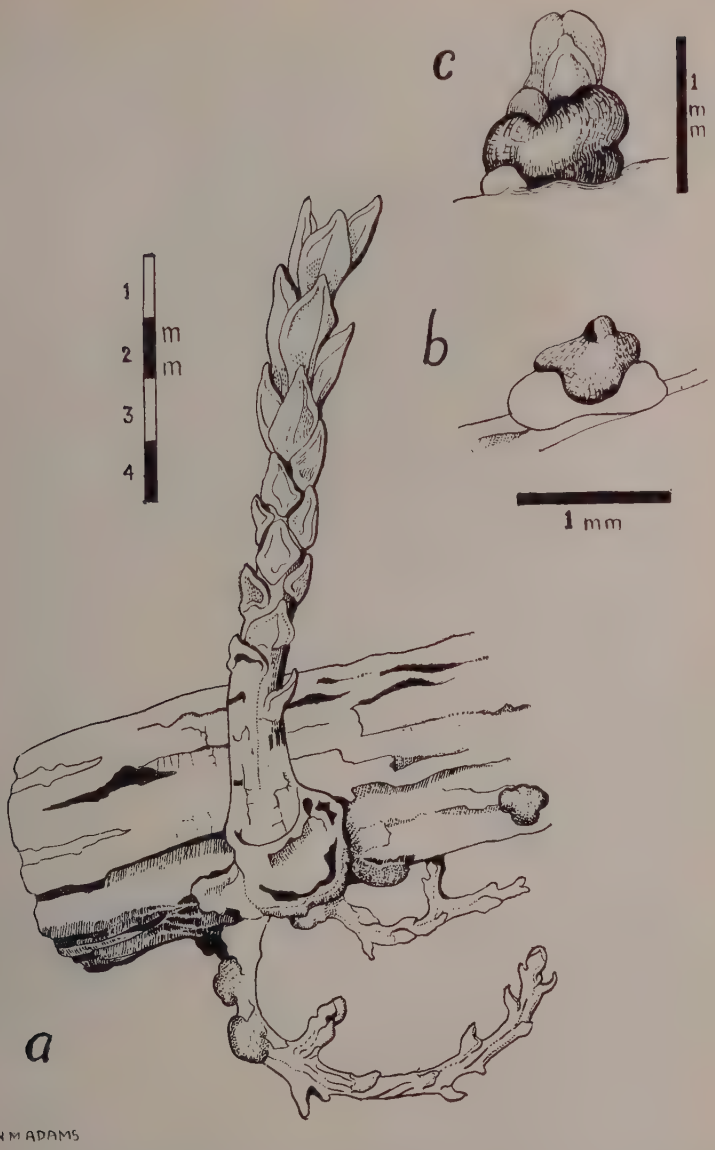

Fig. 2.—a: Adventitious shoots growing from a lateral root. In this figure the shoots are growing from the under surface of the root.
b and c: Stages in the development of buds.

The first leaves of an adventitious root-shoot are scale-like, appressed to the stem, and triangular in cross section. These resemble leaves of an adult plant except that they are not densely imbricated (Fig. 2). As the shoot grows, there is a transition to awl-shaped leaves

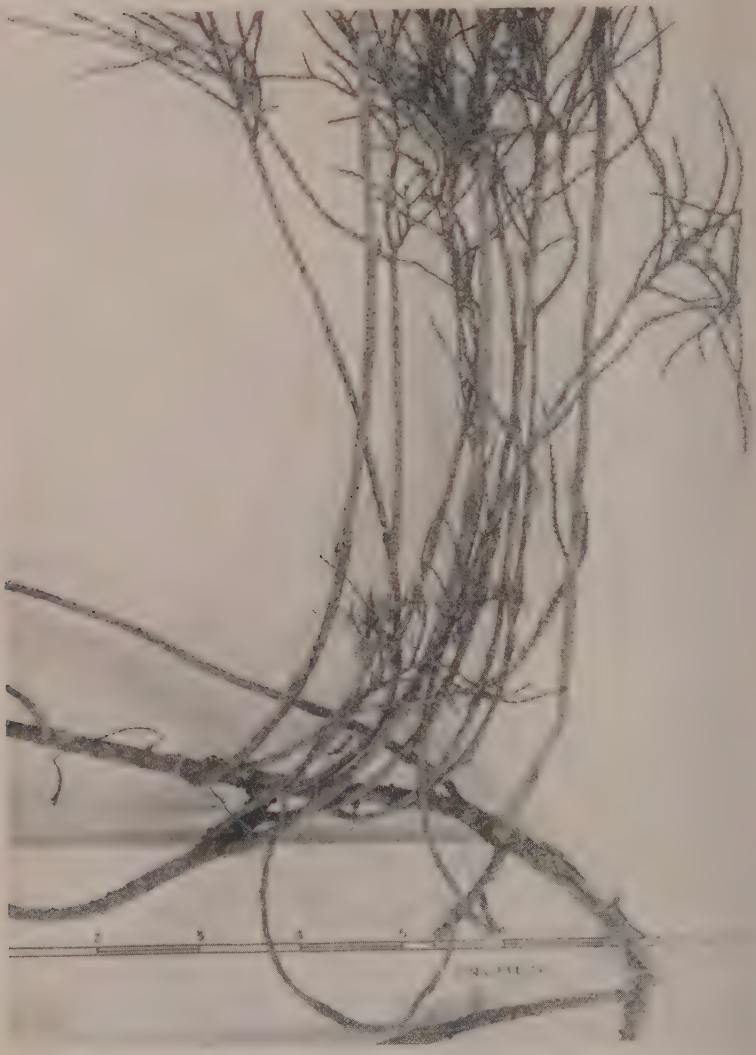

Fig. 3.—Adventitious shoots growing from a lateral root; × 4/5.

which are decurrent at the base and are sharply triangular in cross section, and which are the same as the "intermediate" leaves of plants grown from seed. With continued growth of the shoot there is either a gradual, or an abrupt, transition to lax spreading leaves up to $\frac{1}{2}$ in. long, which are decurrent at the base and are ellipsoidal to flattened triangular in cross section (Fig. 4). Such leaves differ in no way from the juvenile leaves of seedling plants. The adult leaf form is finally attained, although the juvenile stage may persist until the shoot is as much as 12 in. high. The most vigorous development of adventitious shoots occurred in disturbed areas, as at Kokatahi and in Rimu State

Fig. 4.—A clump of adventitious shoots growing from a lateral root. Early stages in shoot formation are faintly visible on the root.

Forest, where the shoots were frequently clumped, and were growing vigorously. In the forest area at Hari Hari in State Forest 41, and wherever tall forest trees were present, clumped saplings were rare, though single saplings of this sucker origin were frequent.

DISCUSSION

McLean and Ivimey-Cook (1951) divide adventitious buds on roots into three categories based on their biological significance. The three categories are:

1. *Reparative*: Buds formed as a sequel to root injuries or to the destruction of the normal shoot system.

2. *Accessory*: Buds formed as part of the normal development in addition to the usual stem buds. These are common in genera such as *Populus* and *Prunus*.

3. *Necessary*: These are buds which are the plant's only means of survival, normal buds being abortive or lacking. *Armoracia vulgaris* (horse radish) is an example.

Following this classification, the adventitious shoots of *Dacrydium colensoi* are considered to be accessory in function, for the buds that occur on lateral roots of trees and saplings have not formed as a result of the destruction of the main shoot system, and there is no evidence that their formation is consequent on root injury.

Available literature makes no reference to the occurrence of adventitious root-shoots in gymnosperms. Holm (1925) states that such shoots are not known in the Gymnospermae and Rauh (1937) makes no reference to the gymnosperms in his exhaustive treatment. Lewis, Dowding, and Moss (1928) report that, in birch bogs in central Alberta, Canada, ". . . it was found that several individual seedling larch trees arose from one long root, no less than 11 seedlings about 1 ft. (30 cm.) high having developed from a root 32 ft. (975 cm.) in length." These authors consider that root fusion may account for the phenomenon, but it is at least possible that the eleven "seedlings" were in fact adventitious shoots arising from the long root. Although no examples of root fusion were noted, it is not impossible that root fusion may occur in *Dacrydium colensoi*, but the accompanying illustrations show that root fusion does not explain these and many other examples seen in the field.

The sequence of adult-type leaves followed by intermediate and then juvenile leaves before the adult leaf form is finally attained is exactly opposite to that found in plants grown from seed. The practical significance of this fact is that it provides a rapid field test for distinguishing young adventitious root-shoots from seedlings. When older plants are growing in clumps, the separation of adventitious root-shoots from seed plants may be made by examining their cones, and if all cones are found to be either male or female, there is good reason for assuming that such clumps are adventitious shoots developed from one lateral root.

That adventitious root-shoots develop into healthy plants, in some areas at least, must be taken into account by the plant ecologist, for their presence would affect the interpretation of transect or quadrat studies. The fact that many shoots develop in clumps suggests a localized factor that stimulates adventitious shoot growth, and the vigour of shoots in logged and burnt areas suggests that the shoots may also function as a rapid means of regrowth. Such shoots may be of value also in the re-establishment of a cover on areas of swamp land that are now regarded as worthless in Westland.

Acknowledgements

I wish to thank the Conservator of Forests, Westland, of the N.Z. Forest Service, for placing transport at my disposal, and in particular

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THE INFLUENCE OF METHOD OF REARING AS HOGGETS* ON THE LIFETIME PRODUCTIVITY OF SHEEP

By I. E. COOP and V. R. CLARK, Canterbury Agricultural College, Lincoln

(Received for publication, 14 June 1955)

Summary

Two groups each of 50 to 60 ewe lambs born in 1946 were reared from birth to 12 months of age on differential high and low planes of nutrition, so that at 12 months the liveweight difference was 30 lb. After 12 months and for the rest of their lives, the two groups were run as one mob. This experiment was repeated with groups of 58 lambs born in 1949 except that the differential feeding extended over the period from 4 to 18 months of age, after which they were run together. At 18 months the liveweight difference was 37 lb. Full lifetime records of production were kept in both experiments.

These experiments gave the following results:

(1) wool production was not affected by the treatments, except as hoggets during the period of the treatments.

(2) milk production, as measured by lamb growth rate, was not affected by the treatments.

(3) reproductive rate appeared to be adversely affected by the low-plane rearing, which increased barrenness in the 1946 sheep and decreased twinning in the 1949 sheep.

(4) mortality of the ewes themselves and of their lambs was slightly increased by the low-plane rearing, but this was not statistically significant.

(5) the productive life of the ewes was reduced by one quarter to one half of a year by the low-plane rearing, as measured by the rate of attrition of incisor teeth.

INTRODUCTION

The New Zealand sheep industry is organized in such a manner that self-maintaining pure-breeding flocks are grazed on hill country or regions of sparse grazing, while sheep and lamb fattening are carried out on intensively managed lowland country. Though an increasing number of fat-lamb producers are breeding their own replacement ewes on lowland country, breeding ewes are not normally bred on this fattening country, the ewes being obtained as surplus breeding stock from the hill country. In fat-lamb production these ewes are crossed with special mutton-type rams, such as the Southdown, to give crossbred lambs.

A feature of this organization is that in general the ewe replacements are reared at least as far as the 2-tooth (yearling) stage, and often to the 5-year stage, on the hill country where they were born. These ewes are therefore reared under conditions that are far from ideal for optimum growth. The nutrition of the lambs is often poor and the climate severe for young growing animals. As a result, mortality

* In this text lamb rearing is deemed to cover the period birth to weaning, and hogget rearing the period from weaning to entry as two-tooth ewes into the breeding flock, even though during this latter period the young sheep is variously referred to as a lamb, hogget, or two-tooth, with no precise definition of each.

for the year following weaning is commonly of the order of ten per cent, and many of the sheep are poorly developed by the time they enter the breeding flocks as two-tooth ewes.

The present investigation was undertaken to determine whether poor feeding and slow development in the first 12 or 18 months of a ewe's life affects its productivity during the remainder of its lifetime. In this way it was hoped to obtain some evidence of what is gained or lost by having our national breeding flock reared under low-plane nutritional conditions.

At the outset it must be stated that there were two restrictive features in the design and execution of the investigation, but these were imposed by the existing facilities available. The first and most important was that the ewes were not reared on hill country at all, but on a lowland farm under poor nutritional conditions simulating hill-country feeding. The farm was, however, one which normally breeds its own replacements. Secondly, the 1949 ewe lambs were obtained from other trials and were not specifically reared from birth to weaning for the purpose under consideration. Nevertheless it is felt that the rates of growth and development were akin to those that occur on hill country, and that the period of artificially retarded growth coincides with that which occurs naturally, namely, from weaning at 4 months of age until the following spring at 12 months of age.

DESIGN OF TRIALS

There were two trials, one commencing in 1946 and known hereafter as the 1946 trial and a second, commencing in 1949 and known as the 1949 trial. In both trials half of the ewes were reared until 12 to 18 months of age on poor feeding conditions (known as the Low Plane, LP) while the other half were well fed all the time (known as the High Plane, HP). This gave poorly developed and well developed two-tooth ewes respectively. From the particular stage decided upon, both lots of ewes were run together for the remainder of their lives, and were treated in the normal commercial manner.

From birth to death, the sheep were weighed periodically and records were kept of all fleece weights, lambing data, rates of growth of progeny, and causes of death. All sheep were identified by eartags. Shearing was usually done in the second half of November of each year, except in 1951 and 1954 when it was two weeks later and earlier respectively than usual. All fleece weights include bellies but not crutchings. Lambs were tagged at birth and weighed at intervals of about six weeks with a final weighing at weaning. The date of weaning varied from year to year according to the seasonal circumstances. Lamb growth rates were calculated for each lamb from its weaning weight and age at weaning.

1946 Trial

240 five-year-old Corriedale ewes were mated to Corriedale rams in the autumn of 1946, at the Kirwee Experimental Farm on the Canterbury Plains. The ewes lambed in September and, as they lambed, half taken at random were transferred to poor pastures (LP) and half to first-class pastures (HP). At weaning in January 1947, there were 53 ewe lambs comprising 32 singles and 21 twins in the HP group,

and 59 ewe lambs comprising 33 singles and 26 twins in the LP group. The mean weaning weights of the lambs, singles plus twins, were—HP 65 lb., LP 57 lb. (see Fig. 1).

After weaning, the HP lambs were grazed on good pasture until May, on chou moellier plus hay from May till August, on Italian ryegrass in August and September, and thereafter on good pasture. Two hoggets died and two were lost off the farm in the 14 months from weaning until mating in 1948. The LP lambs were weaned on to an old browntop-dominant pasture on which they made no live weight gain until the following spring. In the late autumn they became heavily infested with worms and six died before drenching and shifting to a fresh pasture took effect. In the spring and early summer the rapid rate of grass growth made it difficult to maintain the low level of feeding, and all the hoggets made rapid recoveries and substantial weight gains. Through midsummer it was difficult to maintain differential high and low planes of feeding by grazing alone as all paddocks were dry, so that, although the two sets of sheep were not joined together until March 1948, it is considered that the effective period of differential high and low plane feeding ended in August-September 1947. At the end of the winter (August 1947) the weights were: HP 90 lb., LP 60 lb., and in March 1948 HP 105 lb., LP 89 lb. Ten LP hoggets were lost between weaning and mating. At mating in March 1948, both sets of hoggets, now 2-tooth ewes, were put together and run as one mob for the rest of their lives. At the commencement of their breeding life there were 49 ewes in each group, comprising 29 singles and 20 twins in the HP group, and 27 singles and 22 twins in the LP group. Four years later at the conclusion of the trial there were 42 HP and 34 LP ewes.

In 1948, as 2-tooths, the ewes were mated to Southdown rams. In 1949 they were transferred from the Kirwee Experimental Farm to the Ashley Dene farm of Lincoln College and remained there until they were culled for age or died. They were mated to Southdown rams in 1949, and to Corriedale rams in 1950 and 1951. In February 1952 when the ewes were 5½ years old, more than half of them were culled for poor teeth and killed, so the trial finished then.

1949 Trial

This trial was conducted entirely on the Ashley Dene farm of the College. At the end of December 1949, 116 unselected pure Corriedale ewe lambs (born August-September) were tagged and randomized on a liveweight basis into two groups of 58 each. Amongst the 116 lambs were 8 twins, which were divided, four into each group. These lambs up to this stage were reasonably well grown, weighing nearly 70 lb. The LP lambs were maintained on a variety of bare pastures and an occasional spell on turnips throughout the whole of 1950, upon which they made no weight gain at all until the spring, and at the end of the year they weighed 80 lb., after shearing. On the other hand, the HP lambs were grazed on good pasture and made consistent gains throughout the year, finishing with a live weight of 110 lb. Differential levels of nutrition were maintained effectively until the rams were put out in March 1951 when the ewes were then 18 months of age. By this time the mean liveweights were: HP 118 lb., LP 81 lb.

The treatment given the LP lambs was severe. They were long in the leg, slab-sided, light in condition, and inferior in appearance to

the average hill-country two-tooths normally coming on to the market every autumn. Nevertheless, none died during the 15 months' LP treatment, though this is unusual. The HP two-tooths on the other hand were an excellent line, above average standards.

After March 1951, when the ewes were 2-tooths (18 months of age) the two groups were run as one mob, and at no time was any further differential treatment applied. For a month before mating, teaser rams were put out with the ewes, and during mating the normal entire rams were raddled. The purpose of this was to determine whether the onset of oestrus and conception were influenced by the treatment.

The combined mob was maintained together until the autumn of 1955 by which time the ewes had had four lambings. A severe drought in the summer of 1954/5 reduced the feed available on the farm for 1955, necessitating a reduction in stock numbers. It was decided therefore in the interests of continuing other experimental groups of younger sheep on the farm that this particular trial should be closed and all the sheep sold in spite of the fact that most of the ewes could have done another year on the farm. The numbers surviving and identifiable at this date were 49 in the high plane and 42 in the low plane. No ewes were culled at any time except for loss of identity or accidents.

RESULTS

1946 Trial

Live Weight. Fig. 1 shows the live-weight curves of those lambs and ewes that survived to the 2-tooth stage.

It will be seen that the difference of 8-9 lb. weight at weaning was not large, but that from then until the end of the winter (August) a large difference (30 lb.) was established. The HP lambs continued to grow rapidly while the LP lambs barely maintained their weaning weight. From August onwards the 30 lb. difference was gradually reduced, owing largely to the unfulfilled impetus for growth in the undeveloped LP lambs as the warmer weather and better feed conditions of spring and early summer came on. This rapid recovery of growth in hoggets that survive the winter is characteristic of hogget growth. At the time the two groups were amalgamated in March 1948, there was only 16 lb. average difference in live weight. The live-weight curves would indicate that the effective period of differential feeding was only from birth until September 1947, a period of 12 months. During 1948 the weight difference further narrowed until it finally disappeared. Until the beginning of 1949 it was possible to distinguish visually the HP and LP ewes on the basis of conformation, but after the beginning of 1949 this was no longer possible. The LP feeding therefore merely delayed and did not suppress the attainment of "mature" body size and weight.

Mortality of Ewes. In the four years as breeding ewes, the 49 original HP ewes were reduced to 42, giving a mean annual death rate of 3.5%. From the 49 LP 2-tooths in 1948, two were lost off the farm and 13 died, leaving 34 ewes in 1952. The mean annual death rate was therefore 6.5%. While this is perhaps an indication that the LP rearing has weakened the constitution of the ewes, the difference itself is not statistically significant and it has been difficult to find any

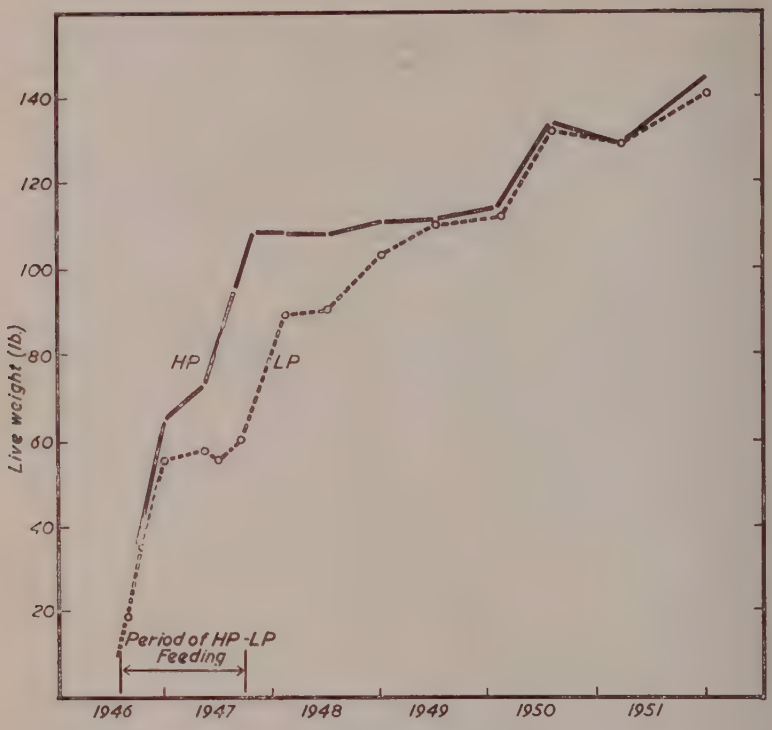

Fig. 1.—Live-weight curves of the high-plane and low-plane ewes of the 1946 trial.

connection between the cause of death and poor development of the ewe. On the evidence, one can only suspect that the LP rearing may have weakened constitution.

Mortality of Progeny. Over the four years, of all lambs born dead or alive, mortality up to the time of weaning was 11% in the HP and 16% in the LP. This difference is not significant at the 5% level. In analysing mortality figures from small groups, considerable caution is necessary. For example, a storm during the 1950 lambing caused a much higher loss in the LP group because more lambs were born in this group during the period of the storm. Nevertheless the losses in the LP ewes were consistently higher than in the HP, and noticeably so in the 2-tooth year where the greatest difference might have been expected.

Barrenness and Prolificacy. The HP ewes had a lower incidence of barrenness than the LP ewes. The percentage of barren ewes was 3% and 8% for the HP and LP ewes respectively over the four years, the difference being statistically significant. Prolificacy was, however, not affected, for the mean percentage of twin-bearing ewes was 25% and 24%.

Wool Production. Table 1 sets out the mean greasy-fleece weights over the 5 years.

TABLE 1. MEAN GREASY-FLEECE WEIGHTS (LB.) OF HOGGETS AND EWES OVER THE PERIOD 1947-51

Group	Hoggets	Ewes				Ewes
	1947	1948	1949	1950	1951	1948-51 (corrected)
H.P.	10.4	9.3	10.4	9.6	10.2	9.84
L.P.	7.7	9.3	10.5	9.7	10.3	9.76

The mean fleece weight (last column) for the four ewe shearings 1948-51 has been corrected for any disproportion of dry ewes, single-bearing ewes, and twin-bearing ewes between groups. The basis of the correction is that on the average dry ewes clip 1½ lb. more, and single-bearing ewes ½ lb. more, than twin-bearing ewes. Over the whole group the correction is quite small and has not been made in individual years. The corrected 1948–51 means are 9.78 and 9.96 for HP singles and twins respectively, and 10.16 and 9.31 for LP singles and twins respectively.

It will be seen from Table 1 that the HP and LP rearing greatly affected the hogget fleece weight (shorn November 1947), a difference of 2.7 lb. being established. This is in line with general experience. However, the effect on the fleece weights in the succeeding years was negligible. LP ewes outclipped the HP ewes very slightly, but as the latter reared more progeny the corrected means for the four years slightly favours the HP group. Statistical analysis of the fleece weights shows only the 1947 hogget-fleece difference to be significant.

As expected, the HP hogget fleeces were longer and stronger than the LP. Mean count of the HP and LP hogget fleeces was 56 and 58 respectively. In subsequent years there were no differences in length, count, character, or yield (percentage clean scoured wool), except that in 1948 there was a one-grading interval advantage in character for the HP ewes.

Lamb Growth Rate. The growth rate of each lamb was calculated from the measured weaning weight minus birth weight divided by age at weaning. Birth weights were not measured, but were assumed to be 10 lb. for singles and 8 lb. for twins and the same for both HP and LP lambs. While the possibility of some difference between the birth weights of lambs from the HP and LP ewes cannot be excluded, any differences must be small and have been disregarded. Even when ewes are differentially fed during pregnancy, group birth-weight differences are small, and in the present experiments both groups were run together throughout all pregnancy periods. The mean growth rates are given in Table 2.

Statistical analysis of the complete 1948/51 data shows the differences to be non-significant. It is obvious that the differences in growth rate are very small and they are not consistent. The same is true when growth rates based on pre-weaning liveweight are considered. The higher lamb mortality in the LP group would tend to enhance the growth rate of this group, as it is usually the smaller and less thrifty lambs that die. However, this could scarcely make the above figures significant.

TABLE 2. MEAN GROWTH RATES OF LAMBS IN POUNDS PER DAY

		1948	1949	1950	1951	1948/51	Total Nos. 1948/51
Singles	HP	0.48	0.50	0.44	0.52	0.485	129
	LP	0.46	0.49	0.40	0.54	0.475	101
Twins	HP	0.38	0.42	0.35	0.47	0.421	74
	LP	0.43	0.42	0.40	0.46	0.430	54

The method of rearing has evidently had no effect on the milk-producing capacity of the ewes, as evidenced by the rate of growth of the progeny.

Longevity. The breeding life of ewes (excluding culling for infertility and disease) is normally decided on the state of the teeth. In February 1952, the poor and broken-mouthed ewes were culled, 45% of the ewes being taken from the HP group and 60% from the LP, showing that the LP rearing had caused more rapid deterioration of the teeth.

1949 Trial

Live Weight. The live weight curves of the two groups are shown in Fig. 2. The treatments were applied from December 1949 to March 1951 and the curves show that these were effective in producing differential growth or weight increase over the whole period except for a few months in the spring. At the time of joining the two groups after the differential treatments, there was a difference of nearly 40 lb. in weight. Thereafter this difference narrowed down rapidly at first to 15 lb. a year later, then more slowly until, four years later at the conclusion of the trial, there was only 5 lb. difference. However, unlike those in the 1946 trial, the LP ewes did not succeed in attaining the live weight of the HP ewes.

The very great effect which these treatments had on the conformation and appearance of the ewes as two-tooths was discernible for nearly two years afterwards, but during the later years of the trial it was no longer possible to pick out the LP ewes except by eartag. At $3\frac{1}{2}$ years, and again at the conclusion of the trial at $5\frac{1}{2}$ years, all the ewes were graded for conformation on the scale: very good 4, good 3, average 2, poor 1. At $3\frac{1}{2}$ years the mean gradings for the HP and LP were 2.3 and 2.4 respectively, and at $5\frac{1}{2}$ years 2.1 and 2.4. This shows that by $3\frac{1}{2}$ years all evidence of previous treatment had been eliminated and at $5\frac{1}{2}$ years apparently reversed. The higher degree of barrenness as two-tooths, and the lower percentage of twins thereafter, would possibly account for the LP ewes regaining a reasonable conformation.

Mortality of Ewes. The recorded losses of ewes were exceedingly light. In the whole four years five ewes died in each group, a mean annual loss of less than 3%. A number of ewes were lost off the farm, some were discarded through losing eartags, and others through accidents. This accounts for the fact that the numbers of ewes identifiable at the conclusion of the trial were 49 HP and 42 LP from the two groups of 58 lambs originally chosen.

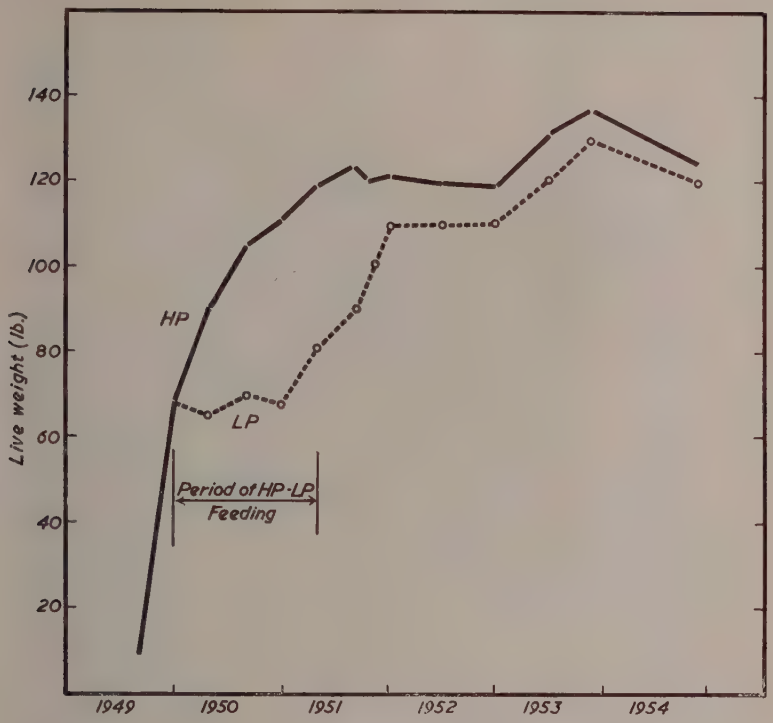

Fig. 2.—Live-weight curves of the high-plane and low-plane ewes of the 1949 trial.

Mortality of Progeny. Records of lambs born dead and failing to reach weaning showed no significant differences between the groups. The mean annual loss up to weaning was 14% for the HP and 16% for the LP. Apart from 1952 when mortality was very high owing to lack of feed (HP 34%, LP 26%) the losses in both groups were always within the limits 9 to 16% which is considered normal.

Barrenness and Prolificacy. The most significant difference recorded in the whole trial was the abnormally high incidence (38%) of barren ewes in the LP two-tooths, compared with 10% in the HP two-tooths, which is lower than is considered normal. In the remaining three years, however, the mean annual barrenness showed no substantial differences—6% in HP, 5% in LP.

The HP ewes were more prolific than the LP. As two-tooths in 1951, the percentage of twin-bearing ewes was 16% in the HP and 3% in the LP. This difference could be attributable to differences in immediate pre-mating treatment, but in the remaining three seasons both groups were run as one mob and the mean percentage of twin-bearing ewes over these latter three years was 40% in the HP and 28% in the LP. This difference is statistically significant.

Wool Production. The mean greasy-fleece weights are given in Table 3.

TABLE 3. MEAN GREASY-FLEECE WEIGHTS (LB.) OF HOGGETS AND EWES

Group	Hoggets	Ewes				Ewes 1952/4 corrected
	1950	1951	1952	1953	1954	
H.P.	11.3	9.4	6.7	10.6	7.8	8.37
L.P.	8.8	8.2	6.9	10.2	8.0	8.32

The 1950 clip was of woolly hoggets (not shorn as lambs) and showed a very significant difference of 2.5 lb. in fleece weight. The mean count and character gradings were as follows: HP, 56/8, good —; LP, 58, medium +. The 1951 fleece showed a difference 1.2 lb. again in favour of the HP group and was no doubt attributable to the 4 months of this period (from November 1950 to March 1951) during which the differential feeding was maintained. However, the three remaining years are strictly comparable, since the two groups were running together for the whole twelve months during the growing of these fleeces. The very poor season of 1952 is reflected in very light fleece weights. The fleece weights of the two groups are similar in each year, while the mean fleece weight over the three years, corrected for disproportionate ratio of dry ewes and twin-bearing ewes (1952/4 corrected), are almost identical. Nor were there any differences in mean count and character over this period.

Lamb Growth Rate. In 1951 and 1952 the ewes were mated to Suffolk rams; in 1953 and 1954 to Corriedale rams. The growth rates have been calculated for each lamb from the weaning weight and an assumed birth weight of 10 lb. and 8 lb. for single and twin lambs respectively. The results obtained are given in Table 4.

TABLE 4. MEAN GROWTH RATE OF LAMBS IN POUNDS PER DAY

		1951	1952	1953	1954	1951/4	Total Numbers 1951/4
Singles	HP	0.40	0.41	0.42	0.54	0.44	109
	LP	0.37	0.41	0.40	0.56	0.43	106
Twins	HP	—	—	0.30	0.39	0.35	78
	LP	—	—	0.30	0.41	0.36	44

In 1951 and 1952 there were too few twin lambs reared to weaning to warrant consideration. There is clearly no difference between the growth rates of the two groups. The small difference in favour of the HP group in 1951 is approaching significance but otherwise none of the differences is significant.

The combined wool production and lamb growth rate for both the 1946 and 1949 trials are shown in Fig. 3.

Longevity. The teeth of the ewes were observed at regular intervals. First in July 1950, when as hoggets they were 10 months old and losing their milk teeth, it was observed that over half of the

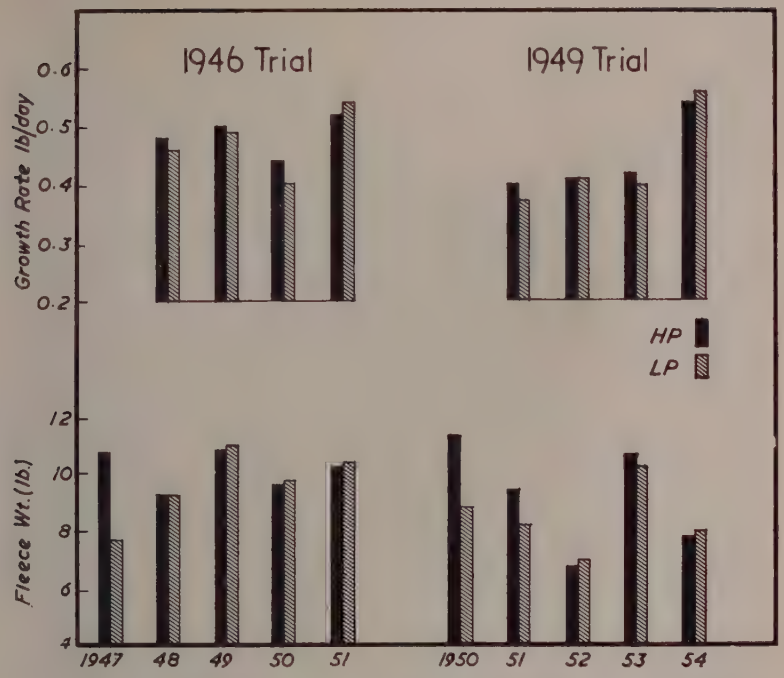

Fig. 3.—Histograms of lamb growth rate (singles) and ewe fleece weight.

LP hoggets had lost all their milk teeth while the HP ewes still had an average of two milk teeth remaining. This difference is most likely due to differences in grazing, especially as the LP hoggets had been on turnips. The next grading was at 2 years of age when it appeared that the HP ewes were more advanced in number of teeth erupted than the LP ewes with means of 4.1 and 3.6 teeth respectively. The third grading at $3\frac{1}{2}$ years showed that all the ewes had six teeth up, but it was evident at this stage that the teeth of the LP ewes were suffering a greater degree of wear than those of the HP. The percentage of ewes in the HP and LP showing signs of what was considered excessive dental wear was 15% and 40% respectively. Finally, when it was decided to conclude the trial at the beginning of 1955 ($5\frac{1}{2}$ years), the ewes were again graded on teeth—this time an estimate being made of the number of years of further useful life left by virtue of the sheep's teeth and on past experience of mouthing old ewes on the farm. The mean values were 1.2 and 0.8 years for the HP and LP respectively. It was considered that nearly half of the LP ewes would have had to be culled for teeth compared with 15% to 20% of the HP ewes.

The $3\frac{1}{2}$ and $5\frac{1}{2}$ year teeth gradings have shown fairly clearly that the longevity of the ewes has been reduced by the low-plane rearing treatment.

DISCUSSION

The effect of the treatments described on the productivity of sheep will be discussed in terms of each of the characteristics measured.

Wool

The evidence that nutritional levels in early life may have an effect on the potential wool-production of the sheep is based on histological studies. It is now reasonably well established that primary follicles have completed their development well before parturition. Secondary follicles commence their development during the last few weeks before parturition, and after birth there is rapid maturation for about 4 to 5 weeks, followed by a long period of slow maturation of at least several months. At birth the secondary:primary (S/P) follicle ratio is of the order of 2 or 3:1 in all breeds, increasing after birth until at maturity it is the order of 5–8:1 in British breeds, and 12–40:1 in Merinos[1, 2, 3].

Schinkel[3], using Merino sheep, first showed that the S:P follicle ratio was lower in twin lambs or single lambs out of maiden ewes than in single lambs out of adult ewes, and further, that it remained lower even at 15 months of age. This suggested that pre-natal and early post-natal nutrition could influence the number of fibre-producing follicles on the sheep and hence conceivably its wool-producing potentiality. The early post-natal treatment is likely to be more important, according to Short[4], since the maturation of follicles in the first few weeks after birth is a more potent influence than the number of follicles present at birth.

The data produced in the present trials suggest, at least in Corriedale sheep, that post-natal nutrition does not influence subsequent wool production. In the 1946 trial the lambs were raised on high and low planes from birth until 12 months of age, with a 30 lb. difference in liveweight at this age. The contemporary effect of this treatment on wool production was quite striking. The fleeces shorn at 18 months of age, from the low plane hoggets, were 2.7 lb. lighter, and were shorter and finer. However, once the differential nutrition ended, the fleece weights were identical during the following four years until the conclusion of the trial. The mean fleece weights of the ewes born as twins was slightly higher than those born as singles in the H.P. group but was 0.8 lb. less in the LP group over the four years following the nutritional treatments. This could be interpreted as supporting Schinkel's suggestion, provided the level of feeding is low enough, but is more likely a random fluctuation due to small numbers in the twin sub-groups.

In the 1949 trial, both sets of lambs were quite well grown until weaning and it was only during the period 4 to 18 months that the differential treatments were applied. This does not cover the most important period of secondary follicle development, and so cannot be used to confirm or refute the suggestion made by Schinkel. However, while it lasted, the low level of nutrition was fairly severe and caused a reduction of 2.5 lb. in fleece weight. But, once again, when the ewes were subsequently restored to identical nutrition there was no difference in weight of wool produced.

One can only conclude therefore that, at least in Corriedale sheep, nutritional treatments applied early in life do not have any effect on the subsequent wool production of the sheep.

Lamb Growth

To our knowledge, no work has been reported on the effect of HP / LP rearing of ewes on their subsequent milk production. In dairy cattle there are several instances in the literature showing that a low level of feeding during pregnancy will depress subsequent milk yield, but these are not comparable with the sheep trials here reported since, in the latter, differential nutritional treatments ceased before pregnancy commenced. On the other hand, experiments recently concluded at the Ruakura Animal Research Station[5] are closely parallel to the sheep trials. In these, dairy cattle were reared on high and low planes until two years of age, after which they were run together. The low-plane rearing depressed the two-year old lactation slightly but at maturity there was almost no difference in the milk yeilds. This would be in general agreement with the sheep trials. In the 1946 trial, the mean growth rates of the lambs were very close indeed—in fact, within experimental error, identical. In the 1949 trial, when the low plane was continued until 18 months of age, the lambs from the LP two-tooths did grow slightly slower than the others, but again over the four years the mean growth rates were to all intents and purposes identical.

From this it is deduced that milk production of the ewes has not been affected in any way by the nutritional treatments. This is perhaps not unexpected. Development of mammary gland tissue takes place during pregnancy, and the two groups of ewes had been amalgamated by the time of the first pregnancy. Also, as Coop[6] has shown, the growth rate of lambs is almost entirely dependent on the level of nutrition after lambing and, again, both groups had identical treatments during all lactation periods. However, what had not been previously demonstrated was that the potential for milk production is not influenced by nutritional treatment and growth rate over the period 0 to 18 months of age.

Fertility

That the reproductive rate of two-tooth ewes can be influenced by the previous nutrition of the ewes as lambs or hoggets is already known, but whether it has any effect beyond the two-tooth stage has yet to be demonstrated. In the U.S.A., Esplin *et al.*[7] conducted experiments over three years along the lines of the present one, comparing lambs wintered on a high plane in the feed lot with lambs wintered on the ordinary winter range, which can be considered to constitute a low plane diet. At the end of the winter both groups were put together on summer range and the subsequent two-tooth lambing (at 2 years of age) compared. Those wintered in the feed lot gave a 65% lambing compared with 46% on the range. In a somewhat similar experiment in Wales, Davies[8] wintered four small groups of hoggets in different localities and then joined them in one mob after the winter. There was a higher incidence of barrenness and a greater lamb loss in the subsequent two-tooth lambing in the group that did very poorly during the winter. Phillips *et al.*[9], by slaughtering sheep at various stages, showed that sexual development was hastened by the good feeding of the feed lot and suggested that differences in two-tooth lambing were due mainly to the stage of sexual development.

Our results partly confirm these observations.

In the 1946 trial, there was no appreciable difference in the performance of the two groups in their first (two-tooth) breeding

season. In the 1949 trial, however, the period of low-plane feeding continued until mating, resulting in very substantial differences at the first mating. Lewis[10] using these particular ewes showed that the mean date of onset of oestrus (that is when 50% have displayed oestrus) was delayed by some three weeks in the LP group relative to the HP group. The subsequent lambing records of the two-tooths showed 38% of barrenness in the LP group compared with 10% in the HP. These differences are statistically significant and are directly attributable to the nutritional treatment. At the first mating the HP groups in both the 1946 and 1949 trials weighed about 110 lb., whereas the LP group weighed 90 lb. and 80 lb. respectively. The 1946 LP ewes made a good recovery in the spring before the first mating, whereas the treatment of the 1949 LP ewes was not only more severe but was also more prolonged.

One can conclude therefore that the effect of prior nutritional treatments on the two-tooths depends to a very large extent on the degree and duration of the low level of feeding and that it can in fairly severe cases have a marked depressing effect in the two-tooth lambing performance.

As to the subsequent performance (i.e., post-two-tooth) the 1946 trial showed that the LP treatment caused an increase in barrenness (HP 3%, LP 8%), but no difference in twinning rate. The 1949 trial, in which there was such a marked difference in barrenness at the two-tooth stage, showed on the other hand no subsequent differences in barrenness, whereas the twinning rate was slightly depressed by the LP (HP 35%, LP 28%). These results are contradictory, and it would not be wise to draw any definite conclusions from them, especially in view of the small numbers used. What is perhaps significant is that the only substantial differences (apart from tooth wear) that have been established by the HP / LP treatments are all in the field of reproduction.

Mortality

For studies of lamb and wool growth, groups of 40 to 50 ewes are considered adequate, but in regard to mortality, where the number of animals that can be considered are the small percentage that die, these numbers are quite inadequate unless very large differences occur.

In the 1946 trial, ewe mortality was higher in the LP group (6%) than in the HP group (3½%), though all of this difference is attributable to a high death rate in the LP group in the final year. The lamb mortality, from birth to weaning including lambs born dead, was consistently higher in the LP group, averaging 16% over the four years compared with 11% in the HP group. In the 1949 trial, there was no difference in ewe mortality, but lamb mortality was again very slightly higher in the LP group (LP 16%, HP 14%). It is difficult to know what value to place on these records. They show that there are no large differences due to treatment, but that low-plane rearing may cause a slight increase in death rate both of the ewes themselves and of their lambs. Had the milk production of the LP ewes been less than that of the HP ewes, that would have been a possible explanation, but this was not the case.

Longevity

In both trials, longevity as measured by the wear of teeth was decreased by the low-plane rearing. In the 1946 trial, the percentages

of ewes culled for broken mouths at 5½ years was 45 and 60 for the high and low plane groups, while in the 1949 trial the estimated further life of the ewes at 5½ years was: HP 1.2 years, and LP 0.8 years. The permanent teeth are developing during the period before eruption and when the differential nutritional treatments were being applied. One might conclude therefore that the low levels of feeding at 4 to 12 months of age have had a deleterious effect on tooth structure or hardness with the result that the teeth subsequently suffer more easily from abrasion. This does not exclude other possibilties. For instance, the LP ewes eventually regain most of the difference in live weight. This could be due to greater amounts of food eaten and hence greater abrasion. It is usually considered that sheep reared and run on the hills have teeth that last longer than those of sheep reared on good lowland pastures. But whether this is an effect produced at the hogget or the adult stage, or whether it is due to differences in the chemical composition of hill pastures is not known. Leslie[11] obtained some evidence that strongly supports the present observations. He compared incisal attrition in ewes that had been bred and reared on different properties but bought-in to the same farm as well grown or poorly grown two-tooths, and found that the poorly developed two-tooths suffered a higher degree of tooth wear in later life, especially if they became pregnant as two-tooths.

CONCLUSION

In New Zealand most, though not all, breeding ewes are reared on hill country. Their growth rate from birth to weaning is not good, but at least while they are suckling it is not bad. It is from weaning until the following spring at twelve months of age that growth is retarded and most hogget rearing difficulties are experienced. In our national ewe flock, the growth of almost all the ewes will have been retarded to a varying degree at the very time when they still have a high growth-rate potential. A small percentage of two-tooth ewes would be as well grown as the experimental high-plane two-tooths and a considerable percentage would be as poorly grown as the low-plane ewes. To the extent that the experimental flocks have been able to simulate the natural conditions of growth of sheep throughout the country, they show in particular that low-plane rearing as hoggets causes:

(1) no deleterious effect on subsequent wool and milk production,

(2) a possible slight decrease in reproductive rate and increase in death rate,

(3) a reduction in longevity.

These are important considerations in a large sheep industry. While it may be comforting to know that wool production and milking capacity of the ewe are unimpaired, the experiments suggest that retarded growth rate at the hogget stage is probably one of the causes of low lambing percentage and short productive life of our breeding ewes.

This leads to the suggestion that the care and nutrition of young replacements is more important than has been realized. If a steady growth rate can be maintained over the critical months from 4 to 12 months of age, not only may hogget mortality be reduced, but an extra

2 lb. of wool per head may be grown. This in itself must go a long way towards paying the inevitable cost of extra feed grown or fewer ewes carried in order the better to graze the hoggets. If to this be added increments of the order of 1% lower ewe mortality, 2% to 3% fewer barren ewes, 2% to 3% more lambs and ½ to ½ year longer life, the advantages of rearing hoggets well become even more obvious.

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THE COOL STORAGE AND EXPORT OF NEW ZEALAND GROWN WILLIAMS' BON CHRETIEN PEARS

I. THE EFFECT ON KEEPING QUALITY OF SOIL TYPE, PICKING DATE, AND DELAY BETWEEN HARVEST AND COOL STORAGE

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Summary

Williams' Bon Chretien pears were successfully exported from New Zealand to the United Kingdom.

After 50 days' storage at 30-32°F. they arrived in a hard, green condition.

Prompt cool-storage after harvest was essential.

Cool-stored Williams' Bon Chretien pears when handled after ripening almost immediately develop an unattractive dark brown scald-like discolouration of the skin. This detracts from their appearance and market value.

Introduction

The New Zealand Apple and Pear Board decided to export Williams' Bon Chretien pears (hereafter called W.B.C. pears) to the United Kingdom for the first time in 1953. With the co-operation of the Food Investigation Board of Great Britain, selected samples of pears were followed from the orchard to their overseas destination. Comparable samples to those sent overseas were held for the same period in cool store in New Zealand. In this paper are presented results of a comparison between fruit grown on different soil types, picked at different dates, and subjected to varying delay between harvest and entry into cool store.

Material and Methods

Samples

All the fruit was grown in the Hawke's Bay district. Orchards from which samples were obtained were selected prior to harvest, but the actual fruit samples were taken at random from commercial lines as they arrived at the fruit assembly point. Fruit for export had to be delivered within 24 hours of harvesting. Fruit subject to longer periods of delay between harvesting and storage was under the supervision of the author. These delayed storage samples were held at air temperature.

Each sample comprised ten $\frac{3}{4}$-bushel cases; it was hoped that each would comprise two cases of each of the following counts, 110, 120, 135, 150, 165, but in some instances these counts were not available. Each sample was sub-divided into two lots of five cases each. One lot was forwarded to the United Kingdom with the commercial shipment, while the other was held in land store in Hastings for a period equal to the overseas transit period. The total period from harvest to the time of arrival of the ship at London amounted to 50 days.

Temperature

On arrival at the assembly point, flesh temperatures ranged from 62-71°F.; the storage temperature of 31°F. was reached after 4-5 days. Quantities of warm fruit were added daily to the chambers. Experimental fruit was also moved from chamber to chamber at least four times during the storage period. Over most of the period, air temperatures fluctuated between 31° and 34°F. and higher air temperatures were recorded over short periods. Flesh temperatures fluctuated within this range.

Overseas samples were railed to Wellington on 1 February and loaded (*M.V. Sydney Star*) the following day. The flesh temperature had risen to 48°F. while in transit. One sample (A.5) was loaded (*M.V. Australia Star*) on 4 February. On arrival in England, thermograph records from *M.V. Sydney Star* showed that the temperature had fallen to 29°F. in the centre of the stack and to 26°F. on one side. Unfortunately most of the experimental fruit was in this low-temperature zone and samples suffered from freezing injury, from 15% to 100% of fruits in a sample being affected. Sample A.5 reached a steady temperature of 31-32°F. after rising to 38°F. betwen land store and ship.

Examinations

The original intention was that examinations in both England and New Zealand should be synchronized, but differences in atmospheric temperatures between England and New Zealand made this impracticable. After one week at air temperature, fruit in Britain remained hard and green, while fruit held in New Zealand had become over-ripe. Finally the procedure adopted was as follows:

Fruit held in New Zealand. Cases of count 135 were examined one day after the fruit was removed from store. Those cases containing 110 and 120 fruits were examined after 7 days, while those containing 150 and 165 fruits had to be abandoned owing to rapid deterioration.

Fruit shipped to the United Kingdom. On arrival, pears were placed in a room at 50°F. This temperature is about average for unheated warehouses at the end of March in southern England.

Fruit from M.V. Sydney Star. Boxes of count 135 were examined one day after discharge; boxes of counts 110, 120 and 150 after seven days. Owing to injury from freezing it was considered that detailed examinations were not justified. Some of the fruit of 150 count was transferred to 65°F. for six days following the period of seven days at 50°F., to see whether fruit could be ripened satisfactorily. A detailed examination of this fruit was carried out.

Fruit from M.V. Australia Star. Boxes of count 110 and 165 were examined one day after discharge, counts 120, 135 and 150 after 12 days at 50°F., when a detailed examination was made.

Measurement of skin colour

Colour measurements of the skin of samples of pears were made prior to storage and at all New Zealand post-storage examinations. The standard used was after Tindale *et al.* (1938). In order to obtain a

wider range of numerical colour units than is provided for on the chart, the six panels of the chart were given values of even numbers from 12-2 as the colour changed from dark-green to orange-yellow. This permitted the allocation of odd numbers to colours which fell between two adjacent panels. It must be admitted that the chart was not entirely suitable for measuring all colour differences observed in these samples, particularly when the skin colour was not uniform.

Hardness of the flesh

The fruit of samples held in New Zealand and of similar maturity to those exported was all too hard before and immediately after storage for any measurements to be made with a penetrometer of maximum load 24 lb. fitted with a 7/16 in. head. No measurements were made on these samples at the second post-storage examination, although by then fruit had softened.

Some hardness measurements were made on samples transported to England.

EXPERIMENTAL

The work was divided into three sections as outlined below:

Experiment A—Comparison of fruit from orchards on different soil types.

Sample Number	Orchard Soil Type
A1	Hastings silt loam
B1	Hastings silt loam
C1	Twyford sandy loam
D1	Twyford sandy loam
E1	Havelock sandy loam over clay pan. Irrigated.
F1	Havelock sandy loam over clay pan. Not irrigated.
G1	Kaiapo clay loam on sand
H1	Kaiapo clay loam on sand

Experiment B—Comparison of fruit from one orchard, picked at different times.

A1, A5, A6 } Three successive pickings from orchard on Hastings silt loam.

Experiment C—Comparison of fruit undergoing different periods of delay between harvest and cool storage.

A1	24 hours delay	All fruit from first pick on one orchard.
A2	48 „ „	
A3	72 „ „	
A4	96 „ „	

Note:

1. Sample A1. The same fruit was common to all three experiments.
2. Samples D1, G1, and A6 examined in New Zealand only.
3. Soil types are according to Hughes *et al.* (1939).

A summary of picking, storage, and examination dates is given in Table 1.

TABLE 1. PICKING, STORAGE, REMOVAL, AND EXAMINATION DATES, 1953

Sample No.	Picking Date	Storage Date	Removal from Store	First Examination	Second Examination
Experiment A					
A1	25 Jan.	26 Jan.	18 Mar.	19 Mar.	25 Mar.
B1	,,	,,	,,	,,	,,
C1	,,	,,	,,	,,	,,
D1	Not known	9 Feb.	30 Mar.	31 Mar.	6 Apr.
E1	25 Jan.	26 Jan.	18 Mar.	19 Mar.	25 Mar.
F1	26 Jan.	27 Jan.	,,	,,	,,
G1	5 Feb.	6 Feb.	28 Mar.	29 Mar.	4 Apr.
H1	28 Jan.	29 Jan.	18 Mar.	19 Mar.	25 Mar.
Experiment B					
A1	25 Jan.	26 Jan.	18 Mar.	26 Mar.	25 Mar.
A5	3 Feb.	4 Feb.	25 Mar.	19 Mar.	2 Apr.
A6	10 Feb.	11 Feb.	2 Apr.	3 Apr.	9 Apr.
Experiment C					
A1	25 Jan.	26 Jan.	18 Mar.	19 Mar.	25 Mar.
A2	,,	27 Jan.	,,	,,	,,
A3	,,	28 Jan.	,,	,,	,,
A4	,,	29 Jan.	,,	,,	,,

Fruit held in New Zealand

Results are given in Tables 2 and 3, while the air temperatures obtaining during the post-storage ripening period are given in Table 4.

Core breakdown was the main disorder apparent at post-storage examinations. The severity of this disorder was related to the temperatures ruling during the post-storage period (Table 4), being worse with higher temperature. This is of particular significance in connection with the later examinations in Experiment B. Degree of wilting was negligible; none of it would have reduced the market value of the fruit.

Experiment A—Orchards and soils

Results from Orchard D1 should be ignored in this experiment, for it was discovered after the fruit was examined that an unknown period elapsed between picking and eventual delivery to the cool store. This factor as well as late harvesting may have accentuated the development of storage disorders. The results given for this orchard do, however, add weight to the conclusions obtained from Experiment C.

TABLE 2. PERCENTAGE OF DAMAGED AND SOUND FRUIT AT TWO EXAMINATIONS AFTER 50 DAYS IN COOL STORE IN NEW ZEALAND

Sample No.	Core Breakdown		Flesh Breakdown		Wilt		Fungous Rots		Sound Fruit	
	I	II	I	II	I	II	I	II	I	II
Experiment A										
A1	0	38	0	0	24	7	0	3	76	43
B1	0	33	0	1	4	9	0	1	96	62
C1	0	40	0	9	7	8	0	4	93	20
D1	4	6	3	4	14	29	0	1	71	67
E1	0	69	0	13	25	16	0	14	75	18
F1	0	54	0	1	10	9	0	0	90	44
G1	0	5	0	1	12	9	0	1	88	86
H1	0	10	0	0	6	6	0	1	95	85
Experiment B										
A1	0	38	0	0	24	7	0	3	76	43
A5	0	8	0	1	5	8	0	4	100	79
A6	0	1	0	1	2	3	1	5	96	92
Experiment C										
A1	0	38	0	0	24	7	0	3	76	43
A2	0	57	0	1	20	11	0	1	80	33
A3	0	53	0	2	11	12	0	1	89	39
A4	0	78	0	19	17	19	0	2	83	9

I = Examination one day after removal from cool store
II = Examination seven days after removal from cool store

Pears from trees growing on the main soil types in the Hastings district will hold in cool store in a hard, green condition for 50 days at 31-34°F., although there was considerable colour variation between pears within samples (Table 3).

Pears from orchards on Havelock sandy loam, overlying clay pan, ripened faster and developed more core breakdown than pears from other soil types.

Pears grown on Kaiapo clay loam stored better than all others and developed the best flavour and eating quality. Pears from one orchard on this soil type were picked early February but were still stored successfully.

Pears held for seven days after removal from cool store became over ripe and developed breakdown, mainly in the core area, particularly

TABLE 3. COLOUR MEASUREMENTS OF W.B.C. PEARS HELD IN NEW ZEALAND
Samples of 50 pears

Sample	Before Cool Storage		After Cool Storage			
			1 day		7 days	
	Mean	Range	Mean	Range	Mean	Range
Exp. A						
A1	12.5	11-13	10.3	7-12	3.9	2-5*
B1	10.9	8-13	8.8	6-10	4.5	2-6*
C1	11.5	11-12	8.9	7-10	4.4	3-5*
D1	11.0	10-12	8.7	5-10	4.8	3-6
E1	11.1	10-12	10.2	8-11	3.8	3-5*
F1	11.9	11-13	9.3	7-10	4.6	2-6*
G1	11.5	10-12	10.2	7-12	4.0	3-5
H1	10.6	10-11	8.4	7-10	4.7	3-6*
Exp. B						
A1	12.5	11-13	10.3	7-12	3.9	2-5*
A5	10.1	7-11	10.0	7-11	4.5	4-6
A6	9.5	7-11	9.0	5-11	4.5	3-6
Exp. C						
A1	12.5	11-13	10.3	7-12	3.9	2-5*
A2	—	—	9.4	7-11	4.3	3-5*
A3	—	—	8.6	6-10	3.9	3-5*
A4	—	—	8.1	6-10	3.6	2-5*

All measurements are according to arbitrary standards of Tindale *et al.* 1938.
* 20 fruits.

when mean temperatures were above 55°F. during the post-storage period (Table 4).

All pears developed a bright yellow or orange colour with an attractive blush (Table 3). This attractive appearance was marred by the almost immediate appearance of a brown discolouration of the skin, at all points where fruit was handled or touched. This browning would appear to be a major factor in lowering the market value of cool-stored W.B.C. pears. Pears all ripened normally in less than seven days, but, except for those grown on Kaiapo clay loam, the flavour was poor.

Experiment B—Date of picking

W.B.C. pears picked between 25 January and 10 February all turned out in hard, green condition. The higher percentage of sound

TABLE 4. AIR TEMPERATURES IN HASTINGS, NEW ZEALAND, DURING POST-COOL-STORAGE RIPENING PERIOD

Sample No.	Temperatures °F.		
	Mean	Maximum	Minimum
Exp. A			
A1	60	80.1	42.6
B1	60	80.1	42.6
C1	60	80.1	42.6
D1	57	72.5	38.3
E1	60	80.1	42.6
F1	60	80.1	42.6
G1	53	72.5	38.3
H1	60	80.1	42.6
Exp. B			
A1	60	80.1	42.6
A5	59	74.9	38.3
A6	53	61.7	40.4
Exp. C			
A1, 2, 3, 4	60	80.1	42.6

fruit remaining from the third picking after seven days out of cool store can perhaps be accounted for by the lower mean temperature over the post-storage period. Because of the different mean temperatures over the post-storage periods, the results from these three samples are not directly comparable.

Experiment C—Delay between picking and cool storage

Pears picked on 25 January and subjected to delays of from 1 to 4 days before cool storage all remained in a hard, green condition during a period of 50 days in cool store. When removed from store all samples deteriorated rapidly, mostly owing to the development of core breakdown. Percentage of sound fruit remaining decreased with increased delay between harvest and cool store.

Appearance of pears was similar to those in experiment A and B, with no visible differences between treatments.

Fruit from M.V. Sydney Star

As mentioned earlier, owing to freezing injury detailed examinations of this fruit were not warranted. The following observations made by C. R. Furlong, Covent Garden Laboratory, London, substantiate the more detailed results obtained in New Zealand.

On 18 March, the day after discharge, all samples in experiment A and C had an average skin colour of 12 or more, indicating that they were dark green. Some penetrometer readings were made on three samples, A2, A3, and C1, mean values being 19.3, 18.8, and 19.1 respectively. The readings indicate that the fruit was still hard on arrival. After seven days at 50°F. the fruit from this ship was still hard and green (Table 5).

TABLE 5. COLOUR AND HARDNESS OF FRUIT FROM M.V. *Sydney Star*
(Fruit held for 7 days at 50°F. after discharge)

Sample No.	Count	Mean Colour	Mean Hardness
Exp. A			
A1	110	12.0	20.5
	120	12.0	22.5
B1	110	11.6	20.3
	120	11.8	18.8
C1	120	11.0	19.8
E1	110	11.5	22.3
	120	11.0	21.5
	150	10.5	—
F1	120	11.9	21.9
	150	11.5	—
H1	120	11.8	19.9
Exp. C			
A1	110	12.0	20.5
	120	12.0	22.5
A2	110	12.0	22.1
	120	11.6	22.7
A3	110	11.8	21.9
	120	11.8	21.1
A4	120	11.0	19.7

After fruit had been held for a further six days at 65°F. the skin had turned yellow and mostly of colour 2. The quality was poor, the flavour rather abnormal, and the flesh gritty in texture. Core breakdown had developed during this period (Table 6). It can be seen that, in Experiment C, breakdown became progressively worse with increasing delay between harvest and storage, whereas all samples stored within 24 hours were free from this disorder. Comment was also made of the undesirable brown scald marks that appeared once the fruit had turned yellow and soft.

TABLE 6. PERCENTAGE CORE BREAKDOWN OF FRUIT FROM M.V. *Sydney Star* AFTER 7 DAYS AT 50°F. PLUS 6 DAYS AT 65°F. (COUNT 150)

Experiment A		Experiment C	
Sample No.	Core Breakdown	Sample No.	Core Breakdown
A1	0	A1	0
B1	0	A2	20
C1	0	A3	20
F1	0	A4	50
H1	0		

Fruit from M.V. Australia Star

Sample A5 of experiment B in this ship, examined 28 March a day after arrival, showed variable skin colour, while the flesh was softer than fruit from the same orchard picked earlier. Because of the different conditions on the two ships, these differences cannot be related entirely to maturity at harvest. Mean colour and hardness were as follows:

Count	Colour		Hardness
	Mean	Range	
110	8	6-10	16.5
165	8	2-12	17.5

Further examination of this sample was delayed for 12 days. By this time the skin colour had turned yellow and core breakdown had developed, varying between 60% and 100%, most being recorded on the largest fruit.

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THE COOL STORAGE AND EXPORT OF NEW ZEALAND GROWN WILLIAMS' BON CHRETIEN PEARS

II. RIPENING AFTER COOL STORAGE

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Summary

Williams' Bon Chretien pears, hard and green when removed from store after 50 days at 30-32°F., ripened satisfactorily when held for a further 7 days at 50-55°F.

Pears held for a similar period at 40-45°F. did not ripen, and at 60-65°F. became over-ripe.

INTRODUCTION

It has been shown (Padfield, 1955) that Williams' Bon Chretien pears can be cool stored for at least 50 days. Fruit exported to the United Kingdom was landed in a hard, green condition, but did not ripen properly owing to the low air temperatures (40-45°F.) prevailing. Comparable samples held for the same period in Hastings, New Zealand, ripened in less than a week when removed from store, after 7 days many pears being over-ripe. Air temperatures here ranged from 37-80°F. averaging 60°F. These results showed the need for establishing a suitable temperature at which pears could be ripened following cool storage.

1954 EXPERIMENT

Sixteen cases of Williams' Bon Chretien pears, all of count 150, were obtained from orchard A (Padfield, 1955). The fruit was picked on 24 January and stored the next day. They were all held at 30-32°F. for 50 days, after which four cases were held for seven days at each of the following temperatures:

(a) 40-45°F.

(b) 50-55°F.

(c) 60-65°F.

(d) Air temperature (51.5-82°F., mean 66.9°F.)

At the end of this period, measurements for colour and hardness were made on samples of 50 fruit from each treatment, while a fuller external and internal examination was made of all fruit in each treatment.

RESULTS

On removal from cool store all fruit was hard, dark green, and unripe. At the end of the post-cool-storage period the effect of temperature on skin colour and flesh hardness was most marked.

The mean skin colour of sample (a) was 9, ranging from 7-11, the latter being similar to the colour on removal from cool store. About

one-third of the pears were still too hard for a pressure reading to be made (maximum load of the penetrometer 24 lb.), while the remainder averaged 17.7 lb. pressure which meant these pears were still hard. At least another three days were required for this fruit to soften.

Mean skin colour of sample (b) was 5.0, range 4-7; the pears also carrying a pronounced blush. Average flesh hardness was 4.6 lb. These pears were in excellent, juicy, eating-ripe condition.

Samples (c) and (d) had mean colours of 4.3 and 4.4 respectively, range of colours of both were 3-5; these pears also had a blush. Average hardness was 2.6 and 2-3 respectively, both samples being over-ripe.

The unsightly brown scald-like blemish appeared on all ripe pears that had been handled.

The results of the detailed examination are presented in Table 1.

TABLE 1. PERCENTAGE OF WILT, CORE BREAKDOWN, AND SOUND FRUIT AFTER STORAGE FOR 50 DAYS AT 30-32°F. AND SUBSEQUENT RIPENING AT DIFFERENT TEMPERATURES

Post-storage ripening temperature	Wilt %	Core Breakdown %	Sound Fruit %
40-45°F.	0	0	100
50-55°F.	0	8	92
60-65°F.	4	32	64
Air temperature	2	61	37

Although all fruit held at 40-45°F. was sound, this temperature is unsuitable because the fruit was still hard and green. A temperature of 60-65°F. is unsuitable because of increased core breakdown. At 50-55°F. the percentage of sound fruit was high and the fruit ripened satisfactorily.

It was apparent that this fruit was nearing the limit of its life after 7 days at 50-55°F., and it was thought that a shorter period at this temperature might suffice to ripen the fruit. An experiment to test this was carried out in 1955.

1955 EXPERIMENT

Sixteen cases of W.B.C. pears, all of count 135 were picked from orchard A on 30 January and stored the next day for 50 days at 30-32°F.

As in previous years, fruit was removed from cool store in a hard, green condition, skin colour being 12 or 12+. From cool store, 12 cases were placed in a chamber at 50-55°F. and the remaining 4 in a chamber at 40-45°F. Samples of 4 cases were removed from the first chamber after intervals of 3, 5 and 7 days, and from the second chamber after 7 days.

RESULTS

After 3 days at 50-55°F. all fruit was still hard and green, there being no perceptible change in skin colour; a detailed colour measurement was not made.

After 5 days at 50-55°F. considerable yellowing of the skin had taken place, average colour of a random sample of 50 pears being 7.9 with a range of 7-10. None of the pears were actually ripe but softening and juice production was noticeable. All fruit was cut longtitudinally: 11% had softened to the stage where no hard gritty noise could be heard as the knife passed through the tissue. This suggested an advanced stage of ripening in these particular pears.

After 7 days at 50-55°F. average colour was 5.6, with a range of 5-7 between fruits. All pears were in a canning ripe or eating ripe condition, with no indication of grittiness, the yellower fruit being full of juice and aromatic. None of the fruit had reached the bright yellow stage with the development of blush. They differed in this respect from pears that received similar treatment in 1954. Also they did not develop the unsightly brown, scald-like skin blemish when handled. There was no sign of any wilt or core breakdown.

The sample held for 7 days at 40-45°F. was still hard and gritty when cut, juice was developing, but pears had not developed flavour or aroma; their average skin colour was 8.8, ranging between pears from 7-11. After a further 2 days at air temperature they had softened sufficiently to be eatable, but were still distinctly green.

These results confirmed that a period of 7 days at 50-55°F. is suitable for ripening New Zealand grown Williams' Bon Chretien pears.

Reference

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STUDIES IN USE OF AGRICULTURAL LIMESTONE

III. SOLUBILITY OF LIMESTONE IN ACID SOIL AS INFLUENCED BY TYPE OF STONE AND PARTICLE SIZE

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Summary

1. The lower solubility* of magnesian as compared with calcitic limestones has been well established, but little previous attention has been paid to the influence of the physical properties of the stone. Results of a trial on the solubility in the soil of 25 calcitic limestones at known finenesses, previously reported and discussed in terms of particle size, are now examined further in respect of the influence of type of stone.

2. The rates of reduction of particle diameter are shown to correlate highly with measured properties of the limestones, and a general solution equation is derived covering both fineness and type of stone which provides a high order of agreement ($r = 0.989$) between predicted and observed solution.

3. It is established that, in certain soil conditions, calcium dissolves at the same rate per unit area at all particle surfaces, irrespective of fineness or type of limestone. Progress of solution appears to be governed solely by the ability of the soil to remove calcium ions from the vicinity of the dissolving surfaces. The rates at which particle diameters are reduced are thus inversely proportional to calcium densities, and the empirical concept of reactivity is replaced by the more fundamental related concepts of calcium density and equivalent calcite surface. Hardness of the stone remains a rough guide to solubility, and the belief that soft limestones need less reduction in particle size is in general substantiated.

4. Particle size has a much greater influence on solubility than type of stone. Properties are shown to behave in a regular manner as fineness is varied. There are some minor changes in relative solubility of limes, but all are accountable in terms of their recorded properties.

5. The solution equation clearly defines the relation between fineness and hardness, and provides a ready means of determining how much finer the harder stones must be ground to become equally soluble. It enables an evaluation to be made of the comparative solubilities of samples of agricultural limestone, based on simple properties of the sample, having due regard to both fineness distribution and type of limestone. The evaluation may be made on a long-term or a short-term basis, as desired. The equation offers the possibility of measuring the soil's dissolving power under different soil and climatic conditions, and of taking this into account when prescribing necessary degrees of fineness. South Island (N.Z.) commercial samples examined show an extreme range of 50% in solubility due to the combined effect of variations in fineness and hardness.

6. The differences in solubility so revealed are maximum differences, liable to be reduced to a greater or less extent when field conditions of topdressing or partial admixture in a normally tilled soil are considered. The established simple rule now provides firm ground of understanding from which to approach these more complex situations.

* For convenience, the terms "soluble" and "solubility" are used here in the sense of ease or rate of solution. Likewise, when the term "lime" is used for brevity or convenience, it refers to agricultural limestone and not to burnt lime or calcium oxide.

Introduction

The influence of particle size on the rate of solution and effectiveness of crushed limestone in the soil has been the subject of a large number of investigations. These were reviewed and discussed in a previous paper[1], in which it was shown from new experimental evidence, supported by much of the previously published data, that under certain soil conditions all particles of a given limestone suffer approximately the same rate of diameter reduction by solution, with the result that solution rates of different sieve separates were successfully predicted by the solution equation derived.

The effect of type of limestone, however, has received little attention. To judge from all reports, the most influential inherent character affecting rate of solution is the proportion of $MgCO_3$ contained in the limestone. Numerous workers[2, 3, 4, 5, 6, 7, 8] have reported consistently on the slower solution of magnesian limestones. Schollenberger and Salter[9] deduced an initial rate of diameter reduction in acid soils that was half as great for dolomitic as for calcitic limestone particles; while Kriege[10] found that limestone separates of equal size, but varying from nil to 44% in content of $MgCO_3$, dissolved in an acid solution at rates ranging from 6% to 96% per hour. Schollenberger and Salter[9] detailed a method for predicting the solubility of samples of crushed limestone, taking fineness and magnesium content into account. This will be referred to later.

Apart from such influential variations in their Ca:Mg ratio, limestones vary widely in their hardness, porosity, and texture[11]. By analogy with the differential rates of weathering of exposed limestone outcrops, it has long been supposed that these physical differences must have a significant effect on the rate of solution of the crushed limestone in the soil, and agricultural experience with the use of hard and soft limes has lent some support to this supposition. Many attempts have been made to evaluate the differences in "reactivity" of limestones by chemical methods. Rates of solution of known separates of different limestones have been measured in agitated solvents such as carbonated water[12], buffered acid solutions[7], and a variety of chloride and citrate solutions[13, 14]; while Barnes[15] Webster *et al.*[8], Elphick[11], and others, have attempted to measure the surface accessible to reagent ions by its reaction with oxalic acid and oxalate solutions. This field of study is well reviewed by Schollenberger and Whittaker[14]. A weakness of this approach is that the conditions of solution employed are very different from those obtaining in the soil, where the slower diffusion of calcium ions may well result in little or no solution occuring at the less accessible surfaces of irregular and porous particles. Evidence supporting this view is presented below. Love and Whittaker[16] measured the specific total surface of known separates of a number of limestones by gas adsorption methods. It would seem, however, that a large and variable part of the surface thus measured is not carbonate surface at all, but surface presented by the non-calcareous impurities. Such, at least, was the conclusion of Elphick[11] on obtaining a high negative correlation between water-vapour adsorption and the carbonate content of his samples. This view would appear consistent with the results reported by Love and Whittaker.

Turning to the more direct approach of studying the limestone:soil reaction itself, very little has been done to evaluate the effect of the

physical properties of the limestones. Morgan and Salter[3] measured various physical properties of twelve Ohio limestones, and determined their rates of reaction, at two finenesses, in 2N acetic acid and in two different acid soils. They found a weak correlation between rates of solution in the soils and in the acid solution, but no correlation with any of the physical properties. Unfortunately their limes were applied as fine separates and at a rate of more than three times the estimated lime requirement of the soils. It has been shown[1] that such conditions narrow down any differences in solubility that might otherwise appear. Doak[17] reported on the behaviour of a hard shelly limestone and a fine-grained somewhat chalky stone when applied as pasture topdressing, both limes being used in a coarse and a finely ground condition. The results well illustrate the interactions shown by Elphick[1] to occur between the factors fineness, hardness, and time, when conclusions are being drawn on the relative solubility of liming materials. The hard coarse lime was decidedly slower than the rest in its initial solution, but by the end of two years virtually the whole of the initial dressing of all grades had dissolved. Apart from the two just mentioned, no other attempt to evaluate the effect of physical properties on rate of solution in the soil has been encountered during an extensive perusal of the literature.

INFLUENCE OF TYPES OF STONE

With a view to determining the influence that might be exerted on rate of solution by the inherent properties of the limestones, Elphick[11] made an extensive survey of the chemical and physical properties of South Island (N.Z.) agricultural limestones, and reported subsequently[1] on the measurement of their rates of solution at various finenesses in an acid soil. The results, reported in full, were examined only in relation to the effect of particle size. This paper now reports the effect of type of stone in conjunction with particle size.

Twenty-five limestones, representing the major South Island limeworks, and judged to include all physical variants of likely significance, were subjected to rate-of-solution studies when intimately mixed with an acid soil and held under uniform conditions of moisture and temperature. The whole series of limes was examined at one fineness, 20–40 mesh, while seven of them, representing the major types, were also tested at three other finenesses, the mean particle size of the four separates being known. Full details of the procedure are recorded in the previous paper[1]. Progressive solution curves for each of the 46 treatments were obtained and it was established that solution adhered closely to the rule of equal diameter reduction for all sizes of particle.

The data for the 20–40 separates are summarized in Table 1, which recapitulates for the reader's convenience the brief description of the physical characters of the limestones, together with the more important properties measured. The data for the four different finenesses (Table 2) are considered later. The designation of the limestones by letters of the alphabet, and the use of the terms compact, shelly and crystalline, is the same as that employed elsewhere in the report on their properties.[11].

The wide range in physical character, and in the values for purity and porosity, will be noted. It has previously been shown[11] that the

TABLE 1. PROPERTIES AND RATES OF SOLUTION OF 25 LIMESTONES (20–40 mesh separates)

Designation	Description of Limestone	Purity $CaCO_3$ by Calcimeter	Mean Porosity	Equivalent Calcite Surface (E.C.S.)	Equivalent Gross Volume (V)	Mean Rate of Diam. Reduction (Δ)
		%	%	m.e. %	ml.	inch $\times 10^{-4}$
A	Compact hard grey finely crystalline	81.1	2.3	16.7	0.90	2.09
C	Compact v. hard white marble	97.8	1.2	4.7	0.74	1.70
D	Compact v. hard white fine grain	95.4	4.0	7.5	0.72	1.51
G	Comp. hard white-grey fine grain almost flinty	90.4	8.2	10.2	0.83	1.90
H	Compact v. hard white v. fine grain flinty	79.8	6.1	9.5	0.91	2.07
K	Compact hard white-grey fine grain	71.3	21.0	15.9	1.24	3.11
L	Comp. v. hard grey-brown coarsely crystalline	97.0	3.7	7.0	0.75	2.14
M	Compact mod. hard cream-grey med. grain	77.6	25.1	17.6	1.30	3.61
N	Compact mod. hard white v. fine grain chalky	86.8	24.9	11.9	1.02	3.15
O	Compact mod. hard white-grey fine grain	77.2	—	15.5	1.12	2.76
P	Compact very soft white chalk	80.9	45.9	44.0	1.50	4.73
Q	Shelly mod. soft cream sandy grain	91.2	28.9	13.3	1.09	2.58
R	Comp. hard cream med. grain semi-crystalline	97.1	13.1	9.0	0.82	1.94
T	Shelly soft cream-grey sandy grain glauconitic	83.2	37.3	21.3	1.26	3.49
U	Shelly soft cream-white coarse grain	98.5	48.8	13.8	1.10	2.75
W	Comp. v. hard white fine grain semi-crystalline	96.0	18.4	9.0	0.86	2.21
Y	Comp. v. hard grey finely cryst. almost flinty	97.4	0.6	5.6	0.73	1.81
a	Shelly soft cream-brown sandy grain glauconitic	80.8	29.0	16.9	1.14	2.71
b	Shelly mod. hard cream-yellow coarse grain	94.5	24.0	11.7	0.94	2.21
d	Shelly mod. hard grey-brown coarse grain glauconitic	82.4	32.3	21.4	1.11	2.14
e	Shelly mod. hard cream-brown coarse grain glauconitic	90.1	31.0	12.1	1.06	2.66
f	Shelly mod. hard cream coarse grain glauconitic	89.1	24.5	16.4	1.12	2.65
g	Shelly mod. soft cream-yellow coarse grain glauconitic	95.5	34.5	14.1	1.06	2.64
h	Shelly mod. soft cream-yellow medium grain	93.9	31.1	13.0	1.01	2.17
i	Comp. v. hard brown-grey coarsely crystalline	91.1	—	8.1	0.87	1.90
	Correlation between Δ and listed properties All H.S.	$r =$				
		-0.546	$+0.718$	$+0.834$	$+0.917$	

equivalent calcite surface (E.C.S.) of these separates, measured by a rapid initial surface reaction with oxalic acid, is a function of the purity, porosity, and (to a lesser extent) the particle shape of the limestones, and that these three properties are effectively and conveniently integrated in the simple measure of the equivalent gross volume (V), previously termed apparent volume, of the separates. The values of V were shown to bear a high correlation ($r = 0.953$) with the values of E.C.S. In view of the importance which, as will presently be seen, attaches to the values of V, the simple method used for their measurement has been more closely examined, and the procedure detailed below* is now recommended. The values of V listed in Tables 1 and 2 are those obtained by the revised procedure. They are slightly higher than the original values and show a slightly higher correlation with rates of solution.

The observed percentages of solution after various periods of time were reported in the previous paper[1]. Rates of solution derived therefrom can be expressed in two ways, (a) in terms of percentage loss by weight, (b) in terms of diameter reduction. For the present purpose of comparing the solubilities of the 25 limestones at one fineness there is no point in using both measures of solubility, since they are equally affected by limestone properties, and the values obtained are highly correlated ($r=0.975$). In Table 1, solubilities are expressed in terms of Δ, the mean weekly rate of diameter reduction, in view of the use of this function in the solution equation. For any period of time Δ may be calculated from the solution equation:

$$R = \left(\frac{D - t\Delta}{D}\right)^3 \qquad 1.$$

in which R is the fractional residue after time t, and D the initial mean particle diameter. It was shown[1] that for the coarser particles the

* Measurement of Equivalent Gross Volume (V).
The equivalent gross volume is defined as the gross volume in ml. of the 18-36 B.S.S. separate that contains 1 g. $CaCO_3$ equivalent. About 60 g. of the 10-36 B.S.S. separate (or nearest equivalent) obtained from the sample is washed by decantation in water to slake aggregates and remove material of silt and clay dimensions. After thorough air-drying, the 18-36 B.S.S. separate (or nearest equivalent) is sieved out. A $2\frac{1}{2}$ in. glass funnel is set up over a 25-ml. cylinder, of internal diameter approximately 15 mm., in such a way that their relative positions do not vary and the stream of particles falls vertically and axially in the cylinder. The stem of the funnel should be of uniform bore (not visibly tapering) and of 4-6 mm. internal diameter. In measuring out the charge of 20-25 ml., the sample should not be *poured* from a larger quantity, or size segregation may occur. The charge is tipped quickly into the funnel, allowed to fall freely into the cylinder without vibration or tapping, and its gross volume noted. The charge is weighed, and its percentage carbonate content (P) determined by calcimeter or titration.

$$\text{Then } V = \frac{\text{Vol. of Sep. (ml)}}{\text{Wt. of Sep. (g.) x P (\%)}}$$

The values so obtained are highly reproducible. Likely variations in height of fall, diameter of cylinder, quantity of separate used, or small deviations from the prescribed sieve apertures, rarely affect the result by more than one or two per cent. The diameter of the cylinder is the most influential factor, and larger cylinders and quantities will yield higher values. The basic value of V, that for pure crystalline calcite, is taken as 0.70. A rather higher value is obtained from calc-spar crushed in a mortar, but when the edges of the particles are abraded, as happens in a pulverizing-mill, a value close to 0.70 is obtained.

linear relationship, $t\Delta = D(1 - \sqrt[3]{R})$, holds approximately. The mean values of Δ listed in Table 1 are therefore calculated as the linear regression coefficients of that equation, thus giving due weight to the whole of the solution data. It was also established that differences between limestones, so recorded, are highly significant.

General Solution Equation

The values for Δ range from 1.51×10^{-4} inches for the very hard stone D to 4.73×10^{-4} in the porous chalk P, and fully reflect the physico-chemical differences between the limestones.

The correlation coefficients (H.S.) between Δ and the listed properties are shown at the foot of Table 1. Though mathematically less formal, the estimates of arithmetic mean rate of diameter reduction derived from the smoothed solution curves for a twelve-week period of solution ($\Delta_{0\text{ to }12}$) yield in every case (both in Tables 1 and 2) higher correlations with properties and rates of solution than those given by the listed values of Δ, the gain being as much in some cases as 15%. Thus, for the correlation between $\Delta_{0\text{ to }12}$ (20-40 separates) and V, $r = 0.95$. This is no doubt due to the fact that the values of $\Delta_{0\text{ to }12}$ are less influenced by the deviations from the hypothesis of equal reduction noted in the early stages of solution[1]. In view of the close interrelationship between the properties, discussed elsewhere[11], these high correlations are not surprising. For the same reason, other measured properties such as grindability, equivalent centres, and the secondary reaction with oxalic acid, also correlate highly with Δ. However, the closest relationship is that between the values of Δ and V, and this applies as much to the shelly as to the compact limes. It is supported by the solution data at four finenesses reported below. In view of the direct manner in which V is related, through the functions purity and porosity, with the equivalent calcite surface of the limes[11], this close connection between Δ and V is to be expected; and if this is taken as the fundamental relation to which the experimental results are a close approximation, then it may be written $\Delta = kV$. By substitution, equation 1 then becomes:

$$R = \left(\frac{D - tkV}{D}\right)^3 \qquad 2.$$

in which k is a solution constant whose value is determined by soil conditions. This general solution equation should therefore take account of both particle size and type of limestone as they affect rate of solution under the soil conditions employed. Its validity is demonstrated in Fig. 1 in which the experimental 12-week solution percentages are compared with those calculated from equation 2. This comparison relates to particles ranging in size from 10 mesh to 150 mesh, and to all types of limestone from a dense white marble to a soft porous chalk. The value of k is equal to the mean value of Δ when V equals unity*. The correlation coefficient between actual and predicted solution is 0.989. The unusually high order of this correlation is due to the accuracy with which the equation deals with particle size, superimposed

* Had soil conditions been different, the value of k would be different, and different relative values of R would have been observed, since R is not proportional to k. An example of this effect is noted on p. 255.

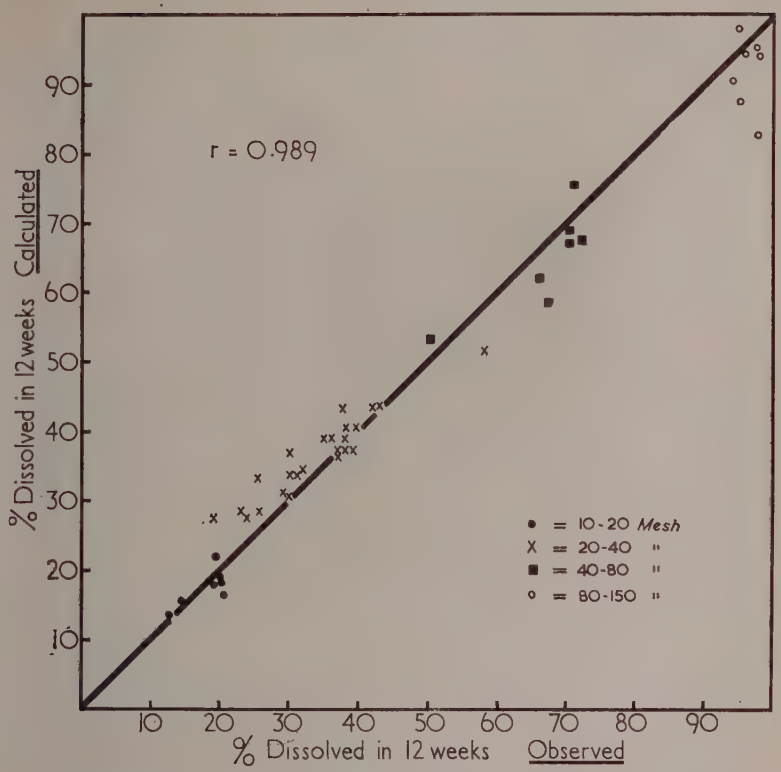

Fig. 1.—Verification of the general solution equation (equation 2) for 25 limestones and four finenesses.

upon the already high correlation betwen Δ and V. It therefore seems justifiable to conclude that under the soil conditions obtaining in this trial the solution of non-magnesian limestones conforms to equation 2. The question of soil conditions is returned to later.

There follows from this a satisfactory explanation of the influence of type of stone on rate of solution. It has been shown that Δ is proportional to V. But, by definition, V is inversely proportional to the calcium density (weight of Ca per unit volume) of the limestones. Therefore Δ × calcium density = constant, which means that the limestone surface is eaten away at a rate that is inversely proportional to its calcium density. It follows, as one might expect, that under the given soil conditions *calcium is dissolving at an equal rate per unit area at all carbonate surfaces,* which statement applies to all sizes of particle (excepting only the initial "spurt"[1] of the finest particles) and to all types of non-magnesian limestone. Thus the more porous and/or impure the particles the faster they dissolve away, for the simple reason that there is less calcium per unit volume. Impurity and porosity are therefore equivalent in their effect to a somewhat finer grinding, since (at a given fineness) they result in unit mass of calcite presenting a greater surface for solution. The empirical concept of "reactivity", which

at times has seemed to imply some unexplained differences in the chemical activity of carbonate surfaces, is thus disposed of, and its place is taken by the twin concepts of calcium density and equivalent calcite surface. From the point of view of the single particle, it is its calcium density that governs its rate of solution; while from the point of view of the equivalent mass of carbonate dispersed at a certain particle size, it is the equivalent number of centres and consequent total calcite surface that governs its rate of solution. The one view is the complement of the other. It is not therefore the hardness of the stone, but its calcium density, measured in terms of V, which governs the rate at which the limestone surface is attacked, although there is found to be a fairly high correlation between the two properties ($r = 0.752$). It therefore seems still legimate to refer in a general way to hard and soft limestones when one really has in mind their differences in ease of solution.

The ability of the solution equation 2 to predict the solubilities of different sized particles of such different types of limestone, leads to the conclusion that the solution of the particles of a sieve separate proceeds as if the particles were uniform spheres possessing the mean diameter of that separate, and that it makes little difference to their *effective* surface whether the exterior aspect of the particles is rotund and smooth, or highly irregular and honeycombed with cellular cavities, as is the case with many of the shelly limes[11]. Combining this last consideration with the conclusion already expressed in italics in the preceding paragraph, it would seem that the progress of solution is governed in the last resort not by what goes on at the intricacies of the actual calcite surfaces but by the ability of the surrounding soil to remove calcium ions from an enveloping shell, more or less saturated with calcium, which surrounds each particle. Such a conclusion might, after all, have been arrived at from first principles. It is consistent with the accepted theory of Noyes and Whitney[19] on the rate of solution of solids in liquids, and lends an added significance to the solution constant k, which is now seen to be a measure of the ability of the adjacent soil to remove calcium ions by diffusion and adsorption from the vicinity of the dissolving surfaces.

Interactions Between Fineness and Type of Stone

The results of solution measurements at four finenesses served primarily to determine the influence of particle size[1]. However, they also provide some confirmation of the relationships revealed by the 20–40 separates, and display some interesting and instructive interactions. The correlations (Table 2) are not so high as those revealed by the larger series of uniform (20–40) separates; but when account is taken of the limited number of very dissimilar limestones, and of the different effects of subdivision on particle structure, it is remarkable that the correlations are sustained so well. As before, the arithmetic mean values of $\Delta_{0\text{ to }12}$ (not listed) provide distinctly higher correlations. Table 2 re-assembles the relevant data for the seven limestones, and includes measurements not hitherto reported on the four separates of each. The values of Δ are the regression coefficients, calculated as already explained. The values of mean rate of solution as well as Δ are listed in this case, since this measure (M.R.) integrates the effects of type of stone with the increasing surface of the finer separates.

TABLE 2. PROPERTIES AND SOLUTION RATES OF SEVEN LIMESTONES AT FOUR FINENESSES

Designation	Mean Porosity	Separates: 10–20					20–40					40–80					80–150				
		P	E.C.S.	V	M.R.	Δ	P	E.C.S	V	M.R.	Δ	P	E.C.S.	V	M.R.	Δ	P	E.C.S.	V	M.R.	Δ
	%	%	m.e. %	ml.	%	inch x 10-4	%	m.e. %	ml.	%	inch x 10-4	%	m.e. %	ml.	%	inch x 10-4	%	m.e. %	ml.	%	inch x 10-4
H	6.1	77.4	6.9	0.94	1.06	2.31	79.8	9.5	0.91	2.17	2.07	81.3	13.8	0.98	6.3	2.52	81.5	24.7	1.03	21.7	2.98
N	24.9	86.7	8.6	1.01	1.32	2.65	86.8	11.9	1.02	2.94	3.15	86.5	18.0	1.14	8.6	3.05	86.3	35.2	1.19	31.8	3.89
R	13.1	96.5	5.5	0.79	0.96	1.80	97.1	9.0	0.82	2.27	1.94	96.9	14.6	0.90	6.6	2.66	95.5	25.5	0.95	21.3	3.14
T	37.3	84.0	14.3	1.14	1.11	2.27	83.2	21.3	1.26	3.45	3.49	85.7	27.7	1.24	8.0	2.65	67.7	52.3	1.47	23.1	3.18
U	48.8	98.4	11.1	1.16	1.47	2.65	98.5	13.8	1.10	3.03	2.75	98.3	20.4	1.11	7.9	2.96	98.9	37.0	1.05	25.0	3.55
Y	0.6	97.5	4.2	0.73	1.00	1.68	97.4	5.6	0.73	2.02	1.81	97.3	9.8	0.81	4.1	1.88	96.6	16.6	0.87	15.6	2.88
e	31.0	84.9	8.4	1.12	1.47	2.47	90.1	12.1	1.06	2.94	2.66	84.3	20.4	1.12	7.1	2.51	69.2	38.2	1.35	19.2	3.23
	Means	89.3	8.4	1.00	1.20	2.26	90.4	11.9	0.99	2.69	2.55	90.0	17.8	1.04	6.9	2.60	85.1	32.8	1.13	22.5	3.26

Correlations: All separates included	r =		V	E.C.S.[1]	M.R.[1]
	All H.S.	Δ	0.690	0.612[2]	0.663
		E.C.S.	0.880[2]		

1. Expressed as percentage of the mean for each separate.
2. Excluding the highly irregular limestone T.

P = Purity of separate (% $CaCO_3$ by calcimeter)
E.C.S. = Equivalent calcite surface (by Oxalic Acid reaction)
V = Equivalent gross volume (ml. per g. $CaCO_3$)
M.R. = Mean rate of solution up to 50% solution (per cent per week)
Δ = Mean rate of diameter reduction of particles

Description of Limestone

H Compact v. hard white v. fine grain flinty
N Compact mod. hard white v. fine grain chalky
R Comp. hard cream med. grain semi-crystalline
T Shelly soft cream-grey sandy grain glauconitic
U Shelly soft cream-white coarse grain
Y Comp. v. hard grey finely cryst. almost flinty
e Shelly mod. hard cream-brown coarse grain glauconitic

The combined effect of fineness and hardness is illustrated in Fig. 2. For purposes of comparison, the complete range of solubilities displayed by 24 limestones at 20–40 mesh, and the abnormal solubility of chalk P, are also shown. The outstanding feature is the dominating influence of fineness on solubility, and the relatively small effect of the type of stone. Differences in solubility (between limes) increase relatively as fineness increases, but at the same time they become less important.

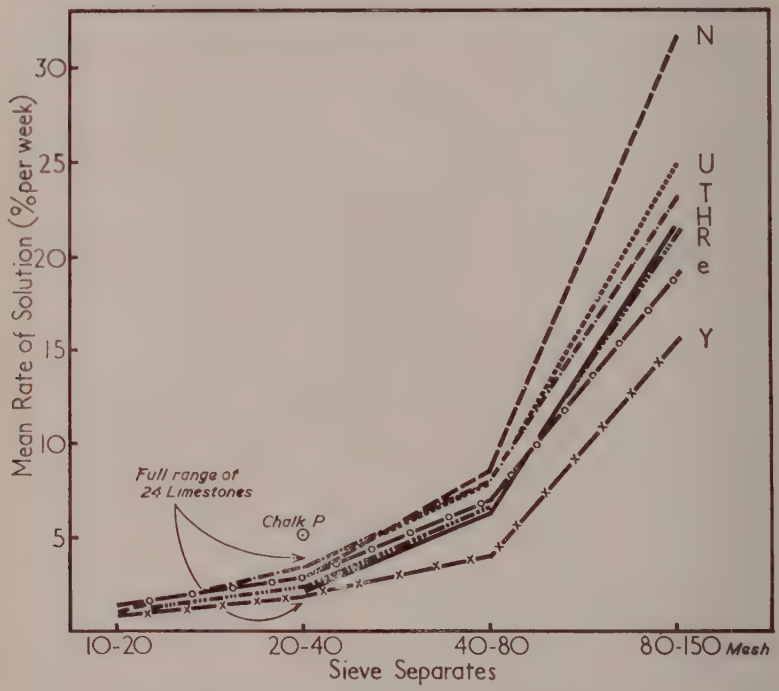

Fig. 2.—Solubilities of seven limestones at four finenesses, in terms of mean rate of solution (up to 50% dissolved in each case.). For comparison, extreme range of solubility of 24 limes at 20-40 mesh. For designation of limes see Table 2.

There is also some change in the relative position of the limes. As fineness increases, the three coarsely porous shelly limes do not gain in solubility by the same proportion as do the compact limes. This is doubtless due to the loss of porosity and consequent gain in the density of the particles of these coarsely porous limes as their particle size is reduced[11]. This irregularity will not materially affect the application of equation 2, since V is measured on the coarser separates, while small differences in solubility of the finer separates are of negligible importance.

Table 2 provides clear evidence of the regularity with which the properties remain nearly constant or vary in a uniform manner as fineness increases. This will be noted first in the values for the means. The exceptions to this rule are of greater interest for the reason that they are all so readily accounted for. Thus, purity changes but little from one separate to another, with two marked exceptions, namely the

80-150 separates of the rather impure coarse shelly limes T and e. These are much reduced in carbonate content owing to the accumulation in them of siliceous sandy impurities. The values for equivalent gross volume (V) are likewise nearly constant (within limes,) a fact which justifies the use of values of V in equation 2 based on one separate (20–40 mesh) of all limes. The minor deviations are all accountable. The four compact limes show a slight rise in V as fineness increases, due to the natural tendency to looser packing with the finer particles; while the slightly declining values of V for the highly pure and porous lime U reveal the loss of porosity by the finer separates. The abnormal values for limes T and e, 80–150 mesh, are associated with the sandy impurities already mentioned. The values for equivalent calcite surface (E.C.S.), determined by the rapid initial reaction with oxalic acid[11], do not increase with anything approaching proportionality to the increasing surface of the separates. Webster *et al.*[8], using Barnes' method[15], report the same discrepancy in their results. Nevertheless, the relative values of E.C.S. (between limes) remain remarkably constant as fineness increases, and, when E.C.S. is expressed as percentage of the mean for each separate, the values correlate well ($r = 0.880$, H.S.) with those of V. (The unusually irregular separates of limestone T being excluded.) This may be compared with the coefficient of 0.953 for these two properties in the case of the twenty-five 20–40 separates.

Turning now to the measures of rate of solution, the mean-rate figures, being a function of total surface, increase from fineness to fineness, whereas the values of Δ remain nearly constant. But, again, when M.R. is expressed as percentage of the mean for each separate, the correlation between the two is fairly good ($r = 0.663$, H.S.). Both measures give expression to real changes that occur in the relative solubility of the limes as fineness increases. In terms of Δ these may be summarized by saying that the compact limes increase somewhat in solubility as fineness increases, due to the initial "spurt" affecting the finer particles; while this gain is rather less in the case of the shelly limes due to their loss of porosity, as already noted. In spite of these interactions, rate of solution (Δ) maintains highly significant correlations with both V and E.C.S. ($r = 0.690$ and 0.612 respectively.) There is a tendency for the shelly limes to display higher values for both V and E.C.S. than their solubility would suggest, a feature which is even more noticeable when initial rates of solution (not listed) are considered. It would seem that irregularity of particle surface, while increasing the measured values of V and E.C.S., has less influence on solubility. This supports the view, already propounded, that the irregularity of particle surface is masked by an enveloping layer of calcium-saturated solution.

PRACTICAL APPLICATIONS

The answers to some practical questions of importance can now be deduced from the general solution equation. One of the problems that promoted these present investigations was that of how much finer the harder limestones should be ground if they are to be made as readily soluble as the soft limestones. The answer to this question is now provided by equation 2, which can be re-cast in the form

$$D = \frac{tkV}{1 - \sqrt[3]{R}} \qquad 3.$$

From equation 3 it follows that, for particles of different limes, the "corresponding diameters" that will dissolve at the same rate, under given soil conditions, are directly proportional to V. This is to be expected, when calcium is dissolving at all surfaces at the same rate. If, therefore, particles of a certain size (mean diameter D_x) of a limestone X of the highest calcium density (V = 0.70) have a certain rate of solution, then the corresponding diameter (D_y) of a limestone Y, for which, say, V = 1.02, will be proportionately greater. Thus $D_y = D_x \times 1.02/0.70$. Moreover, this relationship will hold at all other parts of the fineness scale, and will therefore apply to the whole fineness curve. The "corresponding fineness curve" of limestone Y will therefore be identical in form with that of a crushed sample of limestone X, but shifted laterally in the direction of increasing diameter by a distance equal to log 1.02/0.70, when particle size is plotted on a logarithmic scale[11]. A scale in terms of log V/0.70 can therefore be applied to any point on any fineness curve for the purpose of locating corresponding points for other limes, as has been done in Fig. 3. Corresponding curves, not shown, for the two limestones N (moderately hard chalky stone V = 1.02) and C (hard white marble, V = 0.74) show the following fineness distributions. To the extent that equation 2 can be relied on, these two samples would dissolve at the same rate.

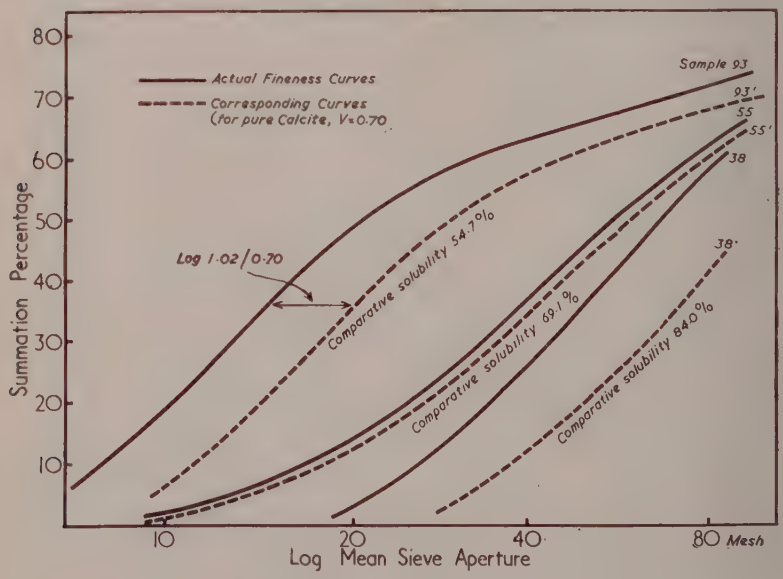

Fig. 3.—Use of corresponding curves in evaluation of comparative solubilities of three samples of crushed limestone. (see Table 3)

A related practical requirement, equally important, is some means of integrating the effects of fineness and hardness so that the relative solubilities of commercial samples of different limestones might be assessed from easily determined properties of the samples. Such a procedure would enable a "minimum solubility" figure to be adopted and so serve as a check on the adequacy of grinding of different supplies of

Sieve Separates	Limestone C V = 0.74	Limestone N V = 1.02
	%	%
10-20	Nil	10
20-40	20	22.5
40-80	27	30
80-150	29	24
<150	24	13.5

agricultural limestone, having due regard to their differences in "hardness". Schollenberger and Salter[9] proposed a method of this nature, taking the fineness curve and certain broad classifications into calcitic and dolomitic limestones into account, but they made no allowance for differences in physical properties. Perhaps owing to the absence hitherto of a suitable means of doing this, the present regulations governing fineness of grinding laid down by the N.Z. Department of Agriculture[18] do not take account of the considerable difference between hard and soft limestones.

This can now be done by application of equation 2 in conjunction with the sieve analyses of the samples and the appropriate values of V. The procedure, by two methods (a) direct calculation, and (b) use of corresponding curves, is illustrated in Table 3 and Fig. 3 by reference to three commercial samples of limestone differing widely in fineness and hardness. One has to assume some standard value of tk, representing the effect of an average soil condition operating for time t. The value of R, the fractional residue, may then be calculated from equation 2 for each sieve separate. This has been done in Table 3, using a value of tk = 0.005, which, it is estimated, corresponds to about 12 months' solution in a moderately moist and acid soil. The products of the items in columns 2 and 4 then yield the total solution of the separates under the assumed conditions, whose sum, in the case of Sample 93, amounts to a comparative solubility of 54.7%. For routine evaluation of many samples, a rather involved table could be constructed giving values of R as governed by the three independent variables tk, V, and D. The alternative method, employing the principle of corresponding curves, has the advantage that the percentage solution of each of the separates, once calculated for calcite (column 7), serves for all future evaluations. From the fineness curve* of the sample in question, the corresponding curve for the standard limestone (calcite, V = 0.70) is constructed (Fig. 3), from which are obtained the percentages of the corresponding separates (column 6). The percentage solution of each of these under the assumed conditions is calculated from equation 2, (in this case $tkV = 0.005 \times 0.70 = 0.0035$), and their total solution thus derived (column 8). Their sum is then equal to the percentage solution (comparative solubility) which would be experienced under

* The fineness curves used must, of course, be those obtained by the sieving of water-washed samples, as previously described[11].

TABLE 3. EVALUATION OF COMPARATIVE SOLUBILITY OF 3 SAMPLES OF AGRICULTURAL LIMESTONE (a) BY DIRECT CALCULATION, (b) BY METHOD OF CORRESPONDING CURVES (See Fig. 3)

	Sample 93. V = 1.02						
1	2	3	4	5	6	7	8
		(a) By Direct Calculation tk = 0.005			(b) By Method of Corresponding Curves		
Sieve Separates	Actual Fineness	R	Dissolved	Total Solution of Separates	Corresponding Calcite Separates	Calculated % Soln. of Calcite seps. tkV = 0.0035	Total soln. of Correspond. Separates
	%		%	%	%	%	%
5-10	19	0.858	14.2	2.7	6	10.5	0.6
10-20	30	0.714	28.6	8.6	30	20.3	6.1
20-40	14	0.459	54.1	7.6	21	40.4	8.5
40-80	9	0.129	87.1	7.8	11	71.2	7.8
<80	28	0.000	100.0	28.0	32	99.0	31.7
Comparative Solubility	100			54.7%	100		54.7%
	By Same Methods:						
..	Sample 55. V = 0.75			69.0%			69.1%
..	Sample 38. V = 1.06			84.4%			84.0%

the same conditions by the commercial sample. The two methods give the same result, thus confirming the principle of corresponding curves. In extreme contrast is Sample 38, which is unnecessarily fine (by present standards) even without taking into account its porous and soft nature. It will be noticed (Fig. 3) that in the case of Sample 55, a hard crystalline limestone, (V = 0.75), the corresponding calcite curve is little different from its normal fineness curve. These three samples span the extreme range in solubility that has been encountered in the examination of commercial samples in this laboratory. This indicates a 50% variation in the solubility of South Island agricultural limestones due to the combined effect of variations in fineness and hardness.

A further useful application of the solution equation 2 is that it enables the soil's dissolving power under different soil and climatic conditions to be measured in terms of the constant k. This may be of some practical importance. It will be seen from equation 3 that "corresponding diameters" (in this case of the same lime in different soil conditions) that will dissolve at the same rate are directly proportional to k; which means that the degree of fineness needed is governed as much by k as by V. It has been assumed that k is a measure of the soil's ability to remove calcium ions by adsorption and diffusion from the vicinity of the carbonate surfaces, and when one considers the wide variations that occur in the factors which govern that

ability, principally the factors temperature, moisture status, exchange capacity, and base saturation, it seems likely that within the situations in which liming is practised the value of k must vary considerably. If this proves to be the case (no measurements have yet been made) then the fineness to which agricultural limestone must be ground, for a given rate of availability to be achieved, will depend perhaps even more on the soil and climatic conditions under which it is to be used than on the hardness and calcium density of the stone itself. An exploration of the variations in the value of this constant in different soil types and climatic regions of New Zealand is therefore contemplated.

The methods of evaluation described above are, so far, based solely on straightforward deduction from the general solution equation. The experimental basis of that equation is so satisfactory, however, that it seems justifiable to present the useful practical possibilities arising from it at this stage. Experimental confirmation of these deductions is at present under way.

SUBJECTIVE BASIS OF EVALUATION

The above estimates of the solubilities of three limestone samples are based upon an arbitrary degree of calcium solution which all particles of all samples are presumed to have undergone. It was pointed out in the previous paper[1] that conclusions as to relative solubility are greatly influenced by the magnitude of that assumed degree of solution. In the concluding paragraph it was stated, "whether it be by the hardness of the stone, or the feeble dissolving power of the soil, or the shortness of the period of observation, if d (diameter reduction) be small then differences will be maximal . . . On the other hand, if d be large . . . then differences become minimal, . . .". It will now be clear that the general solution equation gives precise expression to that generalization. The functions t, k, and V are measures of the three factors mentioned, and since $tkV = d$, an increase in any one of them will increase d and reduce the differences (of solution) both between finenesses and types of stone. The experimental results reported here consistently bear this out, so far as t and V affect comparisons. The effects illustrated in Table 4 are typical. No data involving different values of k have been obtained in the present investigations, though it has already been noted[1] that MacIntyre and Shaw found the greater dissolving power of a sub-surface soil horizon to have narrowed the differences between limestones and between their different separates[4].

The evaluations thus made are therefore highly subject to the value of tk chosen; but this carries with it the advantage that comparisons can be made in accordance with the most appropriate values of t and k. According to circumstances, short-term or long-term comparisons may be most valued; alternatively, a high or a low value of k may be most appropriate, according to whether rapid or slow dissolving conditions in the soil are most likely to be involved.

Finally it must not be forgotten that the simple situation embodied in the general solution equation has been demonstrated only for carbonate particles that are incorporated at modest rates into moist and sufficiently acid soil. This qualification was discussed more fully in the conclusion of the previous paper[1]. It appears from work yet to be reported and from topdressing trials still under way, that under other

TABLE 4. EXAMPLES OF DECREASING DIFFERENCE BETWEEN LIMES AND FINENESSES AS t AND V INCREASE

	20-40 mesh	Weeks 3	12	24	
A. Between limes as t increases	a. Limestone Q	9	35	66	% dissolved
	b. Limestone T	14	43	72	% dissolved
	b/a	1.56	1.23	1.09	
	Mean of 7 Limestones	Weeks 3	12	24	
B. Between finenesses as t increases	a. 20-40 mesh	11	34.7	60.3	% dissolved
	b. 40-80 mesh	27.1	66.9	90.0	% dissolved
	b/a	2.46	1.93	1.49	
	12 weeks solution	Limestones R V = 0.82	U V = 1.10	T V = 1.26	
C. Between finenesses as V increases	a. 20-40 mesh	29	38	43	% dissolved
	b. 40-80 mesh	67	70	71	% dissolved
	b/a	2.31	1.84	1.65	

conditions, including topdressing, in which the reacting capacity of the soil in near contact with the lime is more heavily taxed, the value of k, and therefore of Δ, may be suppressed,* and that in consequence of the finer separates producing this effect first, these finer portions may lose much of their superiority in rate of solution. Differences expressed by the general solution equation are therefore maximum differences, liable to be reduced to a greater or less extent under the field conditions of topdressing or partial admixture with a normally tilled soil. The extent and manner of this deviation from the ideal situation represented by the solution equation is now being investigated.

CONCLUSION

The general solution equation derived from these studies has clearly established the relation between fineness and hardness as they govern the solution of crushed calcitic limestone in the soil, and offers by way of certain straightforward deductions the possibility of evaluating agricultural limes in respect of their solubility with due regard both to typical soil conditions of a district and to all possible variations in fineness and hardness of the stone. Although these deductions have still to be confirmed experimentally, many grounds have appeared, in addition to the highly successful prediction of solubility, for accepting the general solution equation as the fundamental rule governing the solution of non-magnesian carbonate particles in the soil. In the first place, the equation is found to give precise expression to the three factors, previously

* This being apart altogether from the effects of periodic desiccation.

identified, which qualify all such comparisons of solubility. Then the equation reveals a situation which might well have been deduced from first principles, namely, that progress of solution is governed by the ability of the surrounding soil to remove calcium ions from the vicinity of the dissolving surfaces, irrespective of the size and nature of the limestone particles, and the corollary to this, postulated by previous workers, that all particles of a given limestone experience the same rate of diameter reduction. The equation is the more acceptable in that it explains the influence of type of limestone in so straightforward and satisfying a manner, replacing the vague empirical concept of "reactivity" with concepts that relate logically to the measured properties of the limestones. Finally, confidence is increased by the fact that minor deviations are so readily accounted for. The fact that in some situations, yet to be properly defined, the simple rule may have to be modified because of variation in the value of k, does not detract from the value of that rule, since it provides firm ground of understanding from which to approach the more complex situations.

Particle size has been shown to be the pre-eminent factor governing solubility, and for this reason differences in grinding needed by the hard and soft stones are less than the variation in limestone properties would suggest. Hardness and softness of the stone remain a rough guide to ease of solubility of different limestones, and the long-held belief that the soft stones need less reduction in particle size is substantiated, subject to the qualification just noted. The combined effect of the extreme range in fineness and hardness so far encountered in South Island commercial samples is to produce a 50% variation in solubility; and although this is in one sense a maximum estimate, it takes no account of the differences in climatic and soil conditions under which the limestones are used. The influence of these conditions remains to be determined.

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LEVELS OF NON-PROTEIN AND AMINO-ACID NITROGEN IN BLOOD OF PASTURE-GRAZING BEEF CALVES

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Summary

The constancy of concentrations of non-protein nitrogen and amino-acid nitrogen in the blood of Aberdeen Angus calves which were grazed on pasture has been studied.

1. Inconsistent fluctuations in concentrations of non-protein nitrogen (NPN) and amino-acid nitrogen per animal and per week were observed.
2. Average concentration of NPN was 41.0 ± 3.62 mg. per 100 ml. of blood.
3. Average concentration of amino-acid nitrogen was 9.33 ± 0.65 mg. per 100 ml. of blood.
4. Experimental animals failed to demonstrate the blood constituent homeostasis shown in studies involving growth-hormone injection in lactating dairy cattle and laboratory animals.
5. Factors contributing to the lack of homeostasis have been discussed.

Introduction

It was demonstrated many years ago that the progeny test is an effective means of increasing the accuracy of identification of genotypes and this method has been used by progressive breeders of livestock. While the progeny test does what is claimed, it is not an economically efficient means of identifying genetic potential in such traits as growth rate and meat production efficiency in beef cattle. Nor is the problem resolved by selections based on show-ring standards. What is needed is selection criteria for growth as expressed by rate and efficiency of gain which combine the accuracy of a progeny test with what approaches the economy of a show-ring classification.

If one accepts the theory that the vast majority of traits of economic importance are under the control of a large number of genes of minor effect and that the polygenic complexes influencing early growth also influence growth at later stages of development, some of the time in progeny testing may be eliminated by developing a test applicable at an earlier age. Such a concept demands investigation through new approaches, new techniques, and new experimental methods which force us to give up the familiar for the unknown.

Review of Literature

The anterior pituitary hormones, both directly and indirectly through the secretions of the organs that they influence, exert a profound effect on growth through the utilization and metabolism of carbohydrates, proteins, and fats. This subject has been extensively reviewed by Li and Evans[16], Barker[1], and others. Since true growth is generally regarded

as the accumulation of proteins, it is reasonable to expect that an important function of the growth hormone is to retain nitrogen which, in turn, increases the body protein content. Teel and Watkins[21], working with dogs, reported a drop of 20% to 30% in the non-protein nitrogen (NPN) of blood following injections of growth extracts from the anterior pituitary, and showed that about 70% of the decrease in NPN was accounted for by decreases in amino acids and urea. Gaebler[7], also with dogs, confirmed these findings and in addition found a decrease in urinary nitrogen chiefly at the expense of urea. Farr and Alpert[4] noted a transient fall in amino acids in the plasma of dogs following intraperitoneal injections of a growth-promoting pituitary extract.

Experiments with rats have given similar results. Harrison and Long[12] reported that injections of anterior pituitary into fasted rats caused a decrease in NPN. Later experiments by Marx *et al.*[19] and Fraenkel-Conrat and Evans[5] with partially purified growth hormone confirmed these conclusions. Steele, Reynolds, and Baumann[23] found that diets may cause significant alterations in the amounts of amino acids in mouse urine without any comparable change in the blood levels. Since the growth hormone causes a marked retention of nitrogen and an increase in the protein content of the carcasses of treated animals, it may be regarded as a protein anabolic agent[14]. This being true, the contrasting results obtained with adrenocorticotrophic hormones (ACTH) are not surprising. Gordan *et al.*[9], Marx *et al.*[20] and Li and Evans[16] found that adrenocorticotrophic hormone causes an increase in excretion of urinary nitrogen with a proportionate loss of body weight in the rat. Fraenkel-Conrat and co-workers[6] and Simpson *et al.*[22] showed that liver arginase is increased by the administration of adrenocorticotrophic hormone as well as by certain other adrenal cortical substances, thus having the opposite effect to that of the growth hormone. Since this hormone counteracts the action of growth hormone[20] it is to be expected that ACTH would elevate the concentration of free amino acids in the blood plasma. This may be due to either direct catabolic action of the hormone or an inhibition of the synthesis of tissue protein.

MacDonald[18] in studying the metabolism of rapidly and slowly gaining groups of beef cattle fed *ad libitum*, found that, as rate and efficiency of gain decreased, concentration of urea and amino-acid nitrogen per 100 c.c. of blood increased in a linear manner at both 500 and 800 lb. body weight. These levels were found to be independent of intake of dietary nitrogen. Similar results were obtained when rate and efficiency of gain were plotted against the excretion of urinary total nitrogen and urea nitrogen.

From the foregoing it is evident that differential metabolism and growth express themselves through the intermediary metabolic products of the blood and those excreted in the urine of animals, independent of intake of dietary nitrogen. Should levels of NPN or amino-acid nitrogen in blood be found to remain relatively constant in post-weaning pasture-fed beef calves, a single sample method of predictively selecting calves for subsequent rate and efficiency of gain would be available.

With this objective, an investigation of the constancy of levels of NPN and amino-acid nitrogen in pasture-grazed post-weaning beef calves was undertaken at this Station.

Treatment

Aberdeen Angus beef calves were selected at weaning for this study. The group comprised ten steers and five heifers. All were weaned on 29 December 1953, and commenced the rotational grazing of fields consisting predominantly of ryegrass and clover at that time. A mounted horseman mustered the calves for bleeding at regular weekly intervals. Three steers and three heifers were bled every week, while the remaining nine animals were bled at intervals of three weeks. No attempts were made to diverge from normal farm practice in handling the animals prior to or during the intervals between bleedings. The twelve-week grazing period included a period of approximately six weeks during which pasture was limited by summer drought. Owing to an outbreak of leptospirosis in dairy herds using the stock scales, the experimental calves were weighed only three times: at weaning, once during the experiment, and at the end of the experiment.

Samples of blood (15 ml.) were drawn from the right jugular vein of each animal. Stainless-steel bleeding needles were used, and the blood was collected in tubes, using neutral potassium oxalate in preference to other anticoagulants. Haden's modification[11] of the Folin and Wu preparation of protein-free filtrate[5] was used, while concentrations of NPN and amino-acid nitrogen were determined by the methods used previously at this Station[13, 3, 7].

Results and Discussion

Non-protein Nitrogen

The results of analyses of non-protein nitrogen have been presented in Table 1. The average concentration was 41.0 mg. NPN per 100 ml. of blood with a standard deviation of ± 3.62. Values ranged from 30.2 mg. to 50.1 mg. per 100 ml. The average NPN concentration of steers' blood (41.1 mg. N/100 ml.) was higher than that of heifers' (39.7 mg. N/100 ml.). However, this difference was not significant (Table 1). The standard deviation given would indicate that if a ranking order or an individually characteristic non-protein nitrogen level were to be found, the endocrine homeostatic influences would be of a high order indeed. Unfortunately this was not the case. An examination of the NPN values of the six animals that were bled at weekly intervals (Fig. 1) indicates that, while some animals consistently tended to show values that were higher or lower than average, the ranking order was not consistent and the variation within animals from week to week was marked.

Several factors may contribute to such variations in results. First, owing to summer drought, the fodder available, while energetically adequate, was quantitatively deficient. This was indicated by the growth of the experimental animals. Rate of gain during the dry period was only 40% of that recorded following the resumption of pasture growth. Second, all animals were mustered by a herdsman on horseback with the aid of dogs. The animals were then secured by a head gate and bled. Such procedures, while agriculturally commonplace, may well have imposed differentially disturbing effects on the endocrine mechanisms controlling the levels of non-protein nitrogen. Third, and least likely, the method of chemical analysis may be less

TABLE 1. CONCENTRATION OF NON-PROTEIN NITROGEN IN BLOOD (mg. N/100 ml.)

No.	Sex	Week												Average
		1	2	3	4	5	6	7	8	9	10	11	12	
6	F	38.3	39.2	36.7	35.7	37.9	lost	32.8	45.6	38.7	42.4	41.4	37.9	38.8
7	F	39.0	40.7	37.4	36.7	42.0	41.1	38.9	45.2	41.6	47.4	44.6	39.7	41.2
9	F	41.2	40.4	37.1	37.8	39.2	39.9	37.9	45.6	44.0	50.1	44.7	40.6	41.5
15	S	43.8	44.3	37.9	40.4	42.1	42.7	40.0	47.1	45.1	47.5	44.8	45.6	43.4
21	S	41.0	40.4	36.6	37.0	43.6	43.3	41.1	47.1	43.8	48.6	44.1	43.3	42.5
25	S	43.1	44.0	40.5	37.1	42.3	42.9	37.2	41.2	41.8	45.8	42.0	39.4	41.4
1	F			43.1			42.5			41.8			33.3	40.2
5	F	37.2			33.3			33.7			43.2			36.9
11	S		40.5			40.9			44.8			40.4		41.7
12	S	41.3			40.2			40.0			44.9			41.6
13	S		40.7			38.5			42.1			39.2		40.1
14	S		41.7			40.1			45.5			41.0		42.1
16	S	42.5			39.0			38.6			47.2			41.8
17	S			30.6			31.6			38.4			39.0	34.9
27	S			40.5			41.5			43.2			41.1	41.6

critical than required for such a comparison. Fourth, endocrine homeostasis of non-protein nitrogen in beef calves is not maintained within narrow limits.

Amino Acid Nitrogen

The results of analyses of amino-acid nitrogen in blood have been presented in Table 2. The average concentration was found to be 9.33 mg. amino-acid nitrogen per 100 ml. of blood with a standard deviation of ± 0.65. Values ranged from 7.7 to 11.2 mg. per 100 ml.

The average concentration of amino-acid nitrogen in steers' blood (9.4 mg. amino acid N/100 ml.) was higher than that in heifers' blood (9.1 mg. amino acid N/100 ml.) but the difference was not statistically significant. The sex differences for concentrations of both NPN and amino-acid nitrogen are contrary to those found for stall-fed 500- and 800-lb. beef calves[18]. As for NPN, the values for amino-acid nitrogen did not resolve themselves in a consistent ranking order. On examining the data obtained from the six animals that were bled at weekly intervals, some animals showed little or no fluctuation in concentration of amino-acid nitrogen, others fluctuated markedly from week to week (Fig. 2).

It would appear, therefore, that it is not possible to select animals with relatively high or low NPN or amino-acid nitrogen based on a single blood sample under the conditions of this experiment for one or more of the reasons suggested above.

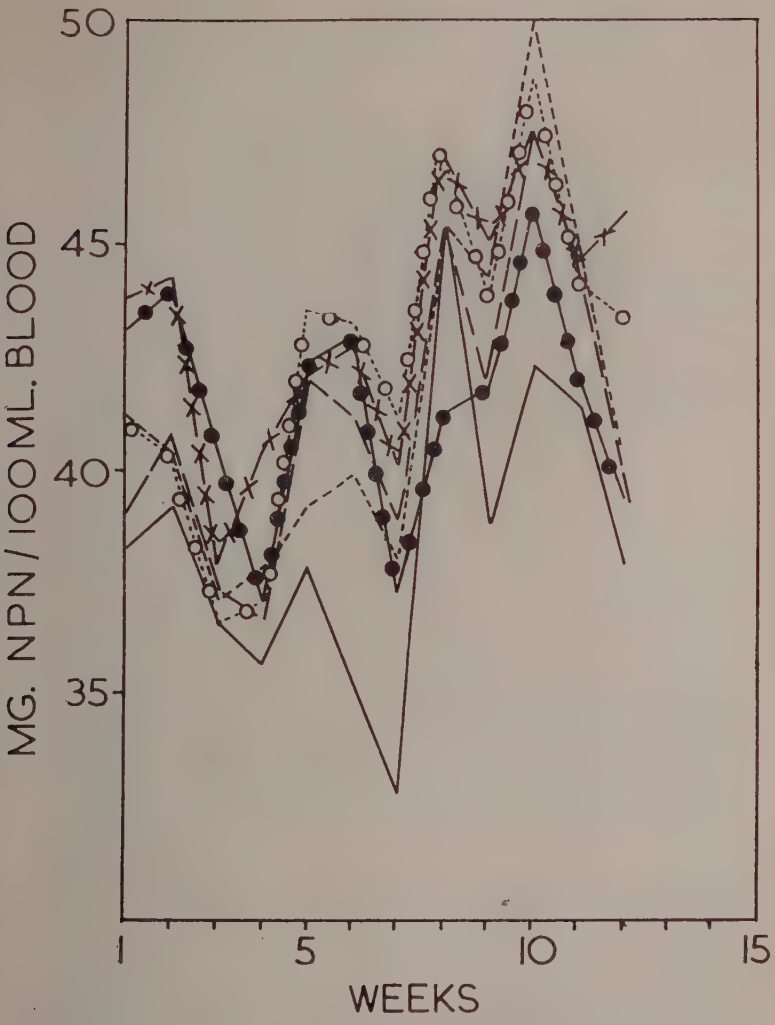

Fig. 1.—Concentration of non-protein nitrogen in the blood of six experimental calves.

A review of the literature indicates that the anterior pituitary affects the utilization and metabolism of a number of specific dietary factors. If an immature animal is placed on a diet of insufficient food intake, growth, as represented by skeletal elongation and gain in body weight, is reduced. Administration of anterior pituitary growth hormone to such an animal results in more rapid growth associated with reduced nitrogen excretion[15, 17]. These findings suggest that the growth retardation during conditions of reduced caloric intake may be due in part to a decreased secretion of somatatrophin. Similarly, "growth hormone" failed to promote an increment in body weight in rats fed

TABLE 2. CONCENTRATION OF AMINO-ACID NITROGEN IN BLOOD (mg. N/100 ml.)

No.	Sex	Week									Av.
		1	5	6	7	8	9	10	11	12	
6	F	8.9	8.8	lost	8.9	8.8	9.1	9.3	9.3	8.9	9.0
7	F	9.7	9.6	10.1	8.9	8.8	9.1	9.9	10.0	9.6	9.6
9	F	8.8	8.9	8.7	8.7	8.7	9.1	9.2	9.9	9.2	9.1
15	S	8.8	10.3	10.1	10.1	10.1	10.1	10.3	10.4	10.3	10.1
21	S	9.3	10.4	8.6	8.9	10.2	9.7	9.6	10.2	9.6	9.5
25	S	8.1	9.1	8.5	8.9	10.1	9.8	9.2	10.8	9.2	9.3
1	F			8.9			8.4			8.9	8.7
5	F	8.8			8.7			9.3			8.9
11	S		9.3			10.0			11.2		10.2
12	S	9.0			10.0			9.1			9.4
13	S		9.1			8.5			9.6		9.1
14	S		9.3			8.8			9.6		9.2
16	S	7.7			8.4			9.7			8.6
17	S			8.7			9.2			9.6	9.2
27	S			8.4			9.2			9.2	8.9

on a low-protein diet[9, 10]. However, supplementing the diet with methionine or increasing the protein content resulted in a significant weight increment following growth-hormone treatment. Since these

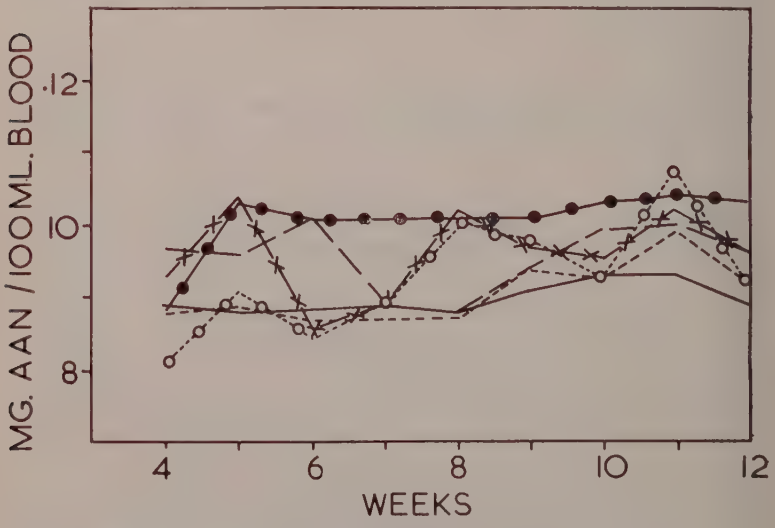

Fig. 2.—Concentration of amino-acid nitrogen in the blood of six experimental calves.

experimental animals failed to attain a daily weight increase commensurate with that recommended[21], it is suggested that plane of nutrition alone was sufficiently low to prevent the adequate expression of anterior pituitary growth-hormone activity. The lack of hormonal homeostasis resulting in inconsistent blood levels of the nitrogen metabolites studied is somewhat surprising. Brumby and Hancock[2] working with identical-twin sets of lactating dairy cows, found that on injection with growth hormone there was a highly significant increase in milk production, but no significant change in NPN concentration in the blood during the injection period.

The negative results obtained have not eliminated the possibility that methods may be developed employing the levels of NPN and amino-acid nitrogen in the blood, whereby a measurment of hormone activity could be obtained in the individual herd replacement animal. The results did indicate conclusively, however, that selections by such a method are not feasible under environmentally limiting conditions such as those experienced by the experimental animals.

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EFFECT OF SHEARING TIME ON WOOL

I. INTRODUCTION

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(Received for publication, 1 June 1955)

Summary

Arguments for and against the growing practice of shearing sheep before lambing are discussed and it is shown that the opinion of many woolbuyers that the wool is unsuitable for worsted combing is contrary to expectation from the available evidence, and is probably due to prejudice against this wool

Introduction

Until recent years it has been customary to shear sheep in New Zealand in late spring or early summer. Breeding ewes have usually been shorn in November-December, or sometimes as late as January, while the dry sheep in a large flock are often shorn a few weeks earlier.

However, in the last few years there has been a growing tendency in the South Island to shear the whole flock in August, a few weeks before lambing commences. This practice has been found to have considerable advantages from the point of view of sheep husbandry. Unfortunately the price obtained for the wool shorn in August has frequently been rather lower than for similar wool shorn in November. This is primarily because the wool is a little different in some characteristics, while in the early stages of the change over of shearing-time wool shorter than usual was produced. Woolbuyers have contended that the wool shorn in August is unsuitable for worsted processing so that in general they are not prepared to pay as much for it. This is probably true of the short wool produced, but it is difficult to see why it should also apply to wool of full length shorn in August.

Pre-lamb-shearing and Sheep Management

Shearing before lambing has considerable advantages from the point of view of sheep management, while there are also some disadvantages.

Advantages

(a) In case of bad weather shorn sheep will tend to look for shelter and take their lambs with them, while unshorn sheep are more likely to stay out and to lose their lambs. Thus there is likely to be less mortality of lambs on this account if the ewes have been shorn.

(b) Lambing is easier when the ewe is not encumbered by her fleece, and also suckling of the lamb is facilitated. This also increases the chances of survival of the lamb.

(c) During November shearing, the lambs are necessarily separated from their mothers for a period, which causes a check in their development. This is avoided by shearing before lambing, or by delaying shearing until the lambs are weaned (January).

(d) When ewes heavy in lamb are carrying a full fleece in early summer there is more tendency for them to be "cast" and be unable to get on their feet again. It is therefore necessary to look them over at least daily to detect any that are cast before they die. This also is avoided by shearing before lambing.

(e) In August there is less other farmwork on hand while at present it is easier to get shearers at that time than in November. This of course depends on the number of farmers who wish to shear at these respective times and a large swing to August shearing could quickly cause a demand for more shearers than are available.

Disadvantages

(a) It is a little more difficult to shear pregnant ewes, which must be handled more carefully, and also to penetrate the wool with the blades or comb. This is said to be "because the grease has not risen", as it is popularly supposed that there is a fairly sudden and marked increase in secretion of wool grease in the spring and that this makes November shearing easier. Alternatively there is the effect of temperature on the fluidity of the grease, and also the probability of a thinning of the wool fibres at lambing-time which would assist penetration later. These aspects will be more fully discussed at a later stage.

(b) There is a risk of loss of the shorn sheep if a spell of severe weather should occur soon after shearing in August. However, experience over the last 10 years has shown that if reasonable care is taken this risk is small if the sheep are kept in or within reach of shelter for about a fortnight after shearing. On the other hand, wintry storms are by no means uncommon in November and can cause considerable losses of newly shorn sheep then, especially as the relative temperature change is likely to be greater.

(c) As shearing must be completed not later than a week or so before lambing is due to commence the period for shearing is rather limited and a spell of bad weather can cause complications.

It is generally considered that the advantages of shearing before lambing outweigh the disadvantages, so that the majority of farmers who have tried this would not go back to shearing at the conventional time and would be prepared to stand some loss on the wool.

PRE-LAMB-SHEARING AND THE WOOL

In addition to the advantages of pre-lamb-shearing from the point of view of sheep management, there are also several factors which would be expected to make the wool superior.

(a) *Break and Tenderness.* In crossbred wools it is often observed that at about lambing-time there is a deterioration in the wool due to a metabolic disturbance. There are probably a number of causes of this, including pregnancy and changes of diet in the winter. The effect observed is a thinning and tenderness of the wool fibres at that time; in severe cases many of the fibres cease growing altogether for a period, resulting in a level of more or less discontinuity in the staple which is referred to as a "break". Further, felting of the free root ends of the

fibres which have stopped growing will probably occur, resulting in "cotting" of the fleece which means that the fibres are matted together in a strongly coherent mass which makes the fleece difficult to process. The metabolic disturbance is also frequently associated with the production of abnormal quantities of water-soluble suint containing yellow pigments which may be removable on scouring, or may permanently stain the wool (canary stain).

When the wool is shorn in November, i.e. about two months after the disturbance, the faulty place will be located about an inch or so from the root end of the staple. When the wool is processed the fibres will break at this point (if not already discontinuous) resulting in many short broken pieces which would form waste in worsted processing. On the other hand if the wool is shorn in August this will be a few weeks before the disturbance and the faulty place will therefore occur close to the tip of the newly growing fibres. As an appreciable length of fibre at the tip of the staple is normally somewhat damaged by weathering in any case, some extra weakness close to the tip will be of little consequence and is of much less importance than if it occurred an inch from the root end.

(b) *Vegetable Matter.* Wool shorn in November may be contaminated by various kinds of vegetable matter ("burr" and "seed") which necessitate extra processing to remove them. Wool shorn in August will be less contaminated by burr and seed, although it may be contaminated by bits of hay, etc. from feeding out.

(c) *Yield.* It is commonly observed that August-shorn wool feels less greasy than November-shorn, so that the yield of scoured wool from the former would be expected to be higher than from the latter.

(d) *Selling-time.* If the wool is shorn 3 months earlier it can of course also be sold earlier, either locally or after shipping overseas. The grower thus gets his cash return earlier while the offering of a considerable quantity of wool earlier in the year enables the wool-selling season to be extended.

On the other hand there are also claimed to be some disadvantages which are the cause of much critical comment by woolbuyers, though it is doubtful whether all of them are real, rather than the result of prejudice. The main points at issue are as follows:

(a) *Openness of the fleece.* While the wool fibres emerge from the sheep's skin in no obvious order or grouping, the fleece is not a uniform mat of fibres like a fur but the fibres are more or less collected into large clumps called staples which can be separated after shearing. In wool shorn after lambing, the staples cling together well so that the fleeces can be handled without breaking up, and in particular they can be opened out on the sorting-table at the mill and the origin of the various parts identified, which facilitates sorting.

On the other hand, fleeces shorn before lambing are often more open in character and tend to break up when handled. Thus by the time it reaches the sorting-table a pre-lamb-shorn fleece may no longer be intact but consist of a collection of pieces which cannot be laid out as a whole and identified. Consequently sorting takes longer.

In the woolstores the clinging together of the staples in the post-lamb-shorn fleeces is attributed to "binders" which are fibres which form small staples which cross from one main staple to another and so bind them together. In the pre-lamb-shorn fleeces the binders are said not yet to have been developed so that the staples are not bound together. No explanation of the possible origin of these binders has been advanced, and it is difficult to visualize how they could be formed except perhaps by some re-arrangement of the grouping of fibres into staples at about lambing-time, perhaps associated with the metabolic disturbances mentioned earlier.

An alternative explanation of the difference in openness of the fleeces is that a small amount of cotting (not enough to be noticeable as such) usually occurs at about lambing-time and this is what binds the staples together in the post-lamb-shorn fleeces while it is of course absent in the pre-lamb-shorn fleeces. Since cotting is synonymous with felting and involves fibre entanglement, if this theory holds, more fibre breakage would be expected to occur in disentangling the fibres of the post-lamb-shorn fleeces which would consequently be inferior to the pre-lamb-shorn fleeces in this respect, although easier to sort.

(b) *Non-conformity to "type".* Wools are classified into a considerable number of standard types according to quality, length, character, and other factors, and these types are used to a considerable extent for particular purposes. Thus wools are ordered by overseas topmakers etc. from the local buyers by type number. As pre-lamb-shorn wools differ from post-lamb-shorn in some respects, particularly openness, they do not always conform to the standard types of the latter. Thus a buyer with orders for certain types of combing wools will pass by pre-lamb-shorn wools although, apart from fleece differences, there is no reason to think the wool itself is appreciably different. The result is that this wool is likely to meet with reduced competition and to fetch a lower price. For example, wools shorn from the same flock of sheep, some before and some after lambing, have been exhibited side by side and buyers have been critical of the former although subsequent manufacturing trials have shown it to be superior.

In fairness it should also be mentioned that some pre-lamb-shorn wool is so noticeably superior that it can be classified with a more valuable type and so obtains a higher price than it might otherwise have done, for example, when the wool is well grown and of good colour so that it can be used for "scouring" (high class woollen) or paper-felts, instead of combing.

(c) *Other characteristics.* In the early stages of pre-lamb-shearing, the wool was necessarily shorter than usual and would naturally be less suitable for combing, apart from the possible effect of other differences. However, the proportion of short wool has now diminished with the shearing of 12 months' growth before lambing, but many buyers still maintain that this wool is unsuitable for combing. They claim that the pre-lamb-shorn wool is "like lambs' wool (because of the openness of the fleeces) and is slippery and produces more waste and noils in carding and combing, while the tops made from it are loose and also the yarn subsequently spun is of hosiery type rather than weaving". It has also been quite seriously stated that "the 'binders' in the fleece are necessary for a good combing performance as they hold the fibres

together and prevent fly"! Further, as the wool is shorn before the spring flush of feed for the sheep and is also less greasy in handle it is said that "the wool fibres are inferior as they have not been adequately nourished when shorn before lambing; the subsequent three months would cause a notable change in the wool fibres, rendering them mature and more amenable to processing".

These arguments when examined carefully in the light of scientific knowledge of the wool fibre and of methods of processing are seen to be largely fallacious or misleading. Some kinds of pre-lamb-shorn wool are undoubtedly like lambs' wool which does not comb at all well, but it does not therefore follow that all kinds of pre-lamb-shorn wool are like this. In processing, the first stage is the complete separation of the fibres from one another by carding and consequently it is difficult to see how the "binders" or the openness of the fleece can have any effect on the subsequent behaviour of the wool in the mill.

With regard to the growth of the wool fibre, arguments that are put forward about the "feeding" of the wool and changes occurring throughout the fibres at lambing-time are fallacious. This is due in part to lack of knowledge of the process of fibre formation. The wool fibre is formed in a "follicle" in the sheep's skin by a continuous process and as more fibre substance is generated the earlier-made material is gradually forced outwards and the length of the fibre gradually increases. The fibre substance (keratin) is completely formed below the level of the surface of the skin and the cells composing the keratin then die and become incapable of further change (apart from the secondary effects of light and weathering on the tip of the fibre). Thus the part of the fibre above the surface of the skin cannot be affected by how the sheep is fed subsequently, and approximately three-quarters of the staple length, corresponding to growth in the period November to August, would be the same whether the wool were shorn in November or August. Any defects in the remaining portion formed in August to November would be at the root end of the November-shorn wool and at the tip end of the August-shorn wool and the wools from the two shearing-times would differ in this respect, the November-shorn wool being much more subject to down-grading owing to the location of any defects near the root end.

It should be borne in mind that with good nutrition the wool fibre is growing continuously during the sheep's life, though with a seasonal variation in rate. Suppose the rate of growth to be 8 inches per year, then in 6 years if the sheep were not shorn the fibres would be 48 inches long. This wool could then be taken and cut into successive 8-inch lengths and it would not be expected to matter where the first cut was made (except that the first and last pieces would not be 8 inches long). Similarly if the wool were shorn in 8-inch lengths from the sheep as it grew the actual (regular) time of shearing would not be expected to matter as regards the wool fibres themselves.

KINDS OF "EARLY-SHORN" AND "PRE-LAMB-SHORN" WOOL

Four kinds of wool can be distinguished that can be classified as early-shorn and/or pre-lamb-shorn. These are as follows:

1. *Pre-lamb-shorn hogget wool.* If hoggets are shorn before lambing time their wool is necessarily shorter, while as the length of the

lamby tip is the same it will form a larger proportion of the whole. Thus the hogget wool besides being shorter will be more lamby in character and in particular will be much more open. It will therefore most likely be unsuitable for Bradford worsted processing. With stable shearing conditions this kind would constitute about 15% of the clip, assuming an economic life of the sheep of 5 years.

2. *Intermediate pre-lamb-shorn wool.* By this is meant the wool produced when a farmer shears after lambing one season and before lambing the next, i.e. it is wool of nine months' growth. Such wool is obtained when a farmer first changes from post-lamb to pre-lamb-shearing, and also if a pre-lamb-shearing farmer buys in sheep that have previously been shorn after lambing. A considerable amount of this wool is naturally produced during the change over of shearing times but subsequently a much smaller amount should be produced when fairly stable shearing times are re-established. As this wool has only had nine months' growth it is generally too short for Bradford combing though suitable for French combing and the woollen trade.

3. *Full-length pre-lamb-shorn wool.* This is wool shorn in successive seasons before lambing, and it would be expected to be little different from wool shorn in successive seasons after lambing, except that it should in general be more free from faults.

4. *Prematurely-shorn wool.* In the North Island there seems to be a tendency to shear dry sheep three times in two years or twice in one year, and this practice naturally produces shorter wool than shearing once a year at a regular time. This shorter wool is similar to that in kind 2 and is similarly too short for Bradford combing. This practice of more frequent shearing is to be deprecated from the point of view of combing, and the financial return to the farmer is unlikely to be greater while he does not have the advantages that arise with respect to lambing and also has to pay additional costs for extra shearings.

In Bradford the term "early-shorn" does not necessarily mean "pre-lamb-shorn", but rather prematurely shorn, i.e. after less than 12 months' growth. It can thus apply to kinds 1, 2, and 4, but does not apply to kind 3.

During the first few years while the practice of shearing before lambing was growing, a considerable amount of short wool of kind 2 came on the market along with kind 1. These kinds were probably tried by some combers and found to be unsuitable on account of their shortness and the lambiness of kind 1. From this it is conjectured that all pre-lamb-shorn wool, including kind 3, has been given a bad name, especially as kind 3 has some of the characteristics of kinds 1 and 2 in that it is usually more open in the greasy state. Kind 2 should diminish to a small proportion of the clip, while kind 1 will necessarily form an appreciable proportion of the clip since hogget wool shorn before lambing time must be shorter.

Since only selected wools of good length are suitable for Bradford worsted combing, and wools unsuitable for worsted can always be absorbed in the woollen industry for other purposes, research has been concentrated on kind 3 of the pre-lamb-shorn wools, of which there is the largest quantity, while the others are unlikely to be suitable for

combing. If this kind were also unsuitable for combing, as many buyers maintain, then the supply of combing wool would be reduced by pre-lamb-shearing, which would be undesirable from the manufacturing point of view.

Experimental work has therefore been initiated to compare the manufacturing performance of pairs of wools of similar quality, one in each case shorn before lambing and the other after lambing. In the first instance suitable lots of wool were purchased at woolstores for processing, but this may introduce a bias in the selection of the lots. Subsequently it became possible to obtain the required two lots of wool from the same flock of sheep which enables a much more satisfactory comparison to be made. At the same time the effect of different times of shearing on the sheep and lambs could also be investigated.

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EFFECT OF SHEARING TIME ON WOOL

II. TRIALS WITH WOOL FROM WOOLSTORES

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Summary

In order to verify or disprove the contentions discussed in Part I, two pairs of wools have been selected from woolstores and processed as far as yarn with observations of their relative performance. One of each pair had been shorn before lambing and the other after. The results of the various tests and observations are presented and it is shown that subsequent to sorting there is little difference in behaviour or performance due to time of shearing.

INTRODUCTION

In Part I the pros and cons of shearing before lambing as opposed to the normal practice of shearing after lambing were discussed and reasons were given for the belief that wool shorn before lambing should not be inferior to wool shorn after lambing. Since many woolbuyers held contrary views, and consequently offered lower prices for this wool, full-scale worsted-processing tests were commenced with the object of verifying or disproving the theoretical expectations. In each test two lots of wool, one shorn before lambing and the other after, have been processed side by side in a mill, and measurements made and samples taken for comparison at appropriate stages.

Two series of tests have been undertaken, differing in the origin of the wools used. In the first series the wools were selected from woolstores as being similar to one another in style and quality. In other words the two wools were matched against one another, thus giving a comparison such as might arise in the ordinary course of wool trading and processing. However, selection of wools on this basis pre-supposes that wools shorn at the two times are similar in many respects to one another and ignores the fact that the conditions of growth of the wools selected may have been considerably different so that the wools may not be really comparable with one another.

In the second series the difference due to different conditions of growth has been minimized by obtaining both lots of wool from the same flock of sheep. These sheep have been kept together and half of them have been shorn in August before lambing and the remainder in November after lambing. Thus differences between sheep are minimized since they are all of the same flock and selected at random for time of shearing, while conditions of feed, weather, etc., are common to both halves except for the period August to November.

Thus in the second series of tests a much truer comparison of the wools is obtained, while in the first series it might be expected that any marked actual differences between the wools might be missed through the method of selection, and that the wools selected might not be representative.

In this paper the results of the two trials in the first series of tests are given.

FIRST TRIAL—CORRIEDALE WOOL

Origin of Wools Used

Two lots of Corriedale wool were purchased at the December 1951 sale at Christchurch. The lots were selected as being very similar to one another in style and quality and had been grown on properties about 25 miles apart in North Canterbury. The actual growing times could not be ascertained exactly as some of the shearing periods were spread over some weeks owing to bad weather. The average growing times for the two lots were 49 and 53 weeks for the pre-lamb-shorn and post-lamb-shorn respectively. That is, there was a probable difference of about four weeks in the period of wool growth.

Sorting

Five bales from each lot were carefully sorted to obtain a main lot of 58s combing. The percentages of the various sorts made were as follows:

	Pre-lamb-shorn (per cent)	Post-lamb-shorn (per cent)
58s combing	37.1	50.5
56s combing	0.3	11.3
58s carding	52.6	20.6
56s carding	1.7	10.1
offsorts	8.3	7.5

A good proportion of the post-lamb-shorn lot was thus found suitable for combing, while the proportion of combing wool from the pre-lamb-shorn lot was considerably lower, indicating that this lot was appreciably shorter. However, this difference in length could have been partly or wholly due to the shorter period of growth of the pre-lamb-shorn wool.

A second noteworthy difference between the two lots was in the time taken for sorting. The fleeces in the pre-lamb-shorn lot were more open than in the other lot, as is often observed, and so tended to break up in the sorters' hands. It was therefore more difficult to sort them efficiently, and sorting took longer.

Combing

The two lots of 58s combing were scoured in succession using soap and soda. In carding there was no noticeable difference between the two lots. The card slivers were oiled with Soluble Wool Oil (Houghton) before combing.

The yields obtained were as follows.

	Pre-lamb-shorn	Post-lamb-shorn
Greasy wool	448 lb.	690 lb.
Scoured wool	322 lb. = 72.0%	478 lb. = 69.3%
Top	282 lb. = 87.6%	416 lb. = 87.0%
Noil	27 lb. = 8.4%	44 lb. = 9.2%
Waste	13 lb. = 4.0%	18 lb. = 3.8%
Tear	7.05 : 1	6.7 : 1
Top (as % of greasy wool)	282 lb. = 63.0%	416 lb. = 60.3%

Thus the combing tear was a little higher for the pre-lamb-shorn lot and the yields of scoured wool and of top were appreciably higher for this lot.

200 lb. of each lot of tops were dyed to a fawn shade and the dyed tops were back-washed and re-combed. The re-combing tears were almost identical for the two lots. A slight difference in handle of the tops was observed, the post-lamb-shorn being somewhat softer than the pre-lamb-shorn.

Spinning

The two lots followed one another down the drawing and were spun side by side. No difference in behaviour between the lots was noticed and the same amount of rubber waste was collected from the finishers, reducers, and rovers, after each lot. The rovings were cap-spun to 1/26s worsted and both lots gave a good spin. The ends down averaged about 5 per 100 spindle-hours for each lot, though half those for the pre-lamb-shorn lot were due to the roving breaking or drafting out behind the back rollers, probably because it was rather lighter than the other.

Fibre Measurements

Measurements of fibre length were made on samples of white and dyed top using the comb-sorter, and fibre diameters were measured using the projection microscope. The results were as follows:

	Pre-lamb-shorn	Post-lamb-shorn
Fibre length, cm.		
White top	11.0	11.7
Dyed top	10.5	11.2
Fibre diameter, microns	28.6	27.9
C. of V., %	20.8	21.2

There was a consistent small difference in length in favour of the post-lamb-shorn lot, indicating that the sorting had not quite neutralized the difference in length of the original greasy wools. The difference in length of the tops was not considered to be of commercial significance.

Yarn Tests

Twelve bobbins from each batch were tested for count, strength, and evenness, with the following results.

	Pre-lamb-shorn	Post-lamb-shorn
Single-thread strength, oz.	5.2	5.3
Single-thread extension, %	8.8	9.0
Hank strength, lb.	41.7	39.7
Worsted count	25.3	25.5
Evenness (Uster C. of V.), %	23.5	24.1

The two yarns were thus identical in the properties measured.

SECOND TRIAL—CROSSBRED WOOL

This trial was conducted in the same way as the first. The wools were bought at Dunedin sales in December 1951 and 1952, but their origins were not known.

Four bales of each lot were used and were sorted for 48/50s, about 10% being rejected from the post-lamb-shorn lot and 25% from the pre-lamb-shorn lot as being too fine. The post-lamb-shorn lot contained a proportion of wool longer than average but this was not rejected.

Combing

There was no observable difference between the two lots on the various machines. The percentages of top, noil, and waste were as follows:

	Pre-lamb-shorn	Post-lamb-shorn
Top	96.4	96.5
Noil	2.9	2.75
Waste	0.7	0.75

Spinning

Rovings (5.5 dram) were made and spun to 1/24s worsted on adjacent sides of two similar machines. The pre-lamb-shorn lot appeared to give the better spin and this was substantiated by observation of ends down during most of a day's spinning, the numbers per 100 spindle-hours being 7.8 and 12.7 for the pre-lamb-shorn and post-lamb-shorn respectively. The two lots were not interchanged to allow for differences between the machines, but it is considered that the differences between the ends down for the two lots is much more than would reasonably be expected to arise from machine differences, and that it therefore indicates that the pre-lamb-shorn lot was giving the better spin.

Fibre Measurements

Fibre length and diameter were measured as before and the following results were obtained.

	Pre-lamb-shorn	Post-lamb-shorn
Mean length, cm.	13.5	13.5
C. of V., %	28.7	28.8
Mean diameter, microns	34.3	35.2
C. of V., %	25.3	27.6

There was no difference in length of the tops, while the pre-lamb-shorn measured slightly the finer. This top had a softer and silkier handle than the other.

Yarn Tests

The results of tests on 10 bobbins from each lot were as follows:

	Pre-lamb-shorn	Post-lamb-shorn
Worsted count	24.4	24.3
Hank strength, lb.	52.2	53.4
Single-thread strength, oz.	6.8	7.3
Single-thread extension, %	15.0	15.9
Twist, t.p.i.	10.7	10.3
Evenness (Uster C. of V.), %		
Roving	10.1	10.0
Yarn	26.9	27.8

The pre-lamb-shorn lot tested slightly the weaker but otherwise there was little difference between the two lots.

Conclusions

1. The pre-lamb-shorn wool took longer to sort than the post-lamb-shorn, as expected, owing to the more open nature of the fleeces.

2. After sorting there was little observable difference in processing behaviour through carding, combing, drawing, and spinning. The pre-lamb-shorn wools were at least as good as the post-lamb-shorn, and were better in some respects. Thus the Corriedale lot gave a rather better combing tear, while the crossbred lot gave a better spinning performance. There was a difference in length between the two lots of Corriedale wool in the grease, the pre-lamb-shorn lot being the shorter, but the difference was due at least partly to the shorter period of growth between shearings in this case.

It is concluded that while there is a difference between the two wools in the grease, this only concerns the fleeces, and there is little difference between the actual wool fibres.

Acknowledgements

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EFFECT OF SHEARING TIME ON WOOL

III. INVERMAY WOOL, 1953

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Summary

In 1953 the two halves of a flock of Romney-cross sheep were shorn in August and November respectively, each shearing being of 12 months' wool. Each fleece was sampled for length, and was weighed and classed. A medium crossbred line was selected from each lot, and this wool was processed through a mill.

The pre-lamb-shorn fleeces were slightly shorter and lighter in weight than the others, but taken overall the grade was much better. The two lots of selected wool behaved very similarly in the mill, except that the pre-lamb-shorn lot gave the better spinning performance and the stronger yarn.

Introduction

In the trials described in Part II the wools were selected at woolstores and came from different farms, so that they were not necessarily comparable with one another, although similar in general appearance. In addition, the wool selected formed only a part of the clip in each case and there was no information as to what proportion of the clip it represented, which has since been found to be a most important factor.

In subsequent work these defects have been overcome by using a flock of sheep half of which are shorn before lambing and the rest after lambing. The sheep used in the trial described in this paper are owned and managed by the Invermay Research Station of the Department of Agriculture.

In 1952 half of a mob of about 300 Romney-cross sheep of various ages and of rather mixed wool quality were shorn on 6 August and the rest on 18 November. Subsequently they were run together continuously, being kept on hill pasture most of the time.

Shearing and Classing

The procedure at shearing was as follows: The sheep were machine shorn by three shearers and as each fleece was shorn it was gathered up and weighed. It was then thrown on the table and skirted, and four staples were taken from along one side for measurement of length (slightly stretched against a ruler to take out the crimp).

The fleeces were classed as fine, medium, or strong crossbred, and graded as AA or A, the A grade including all fleeces of lower grade than AA. The main faults only in the A-grade fleeces were noted.

The data obtained from the fleeces are summarized in Table 1. In November 1953 some of the sheep were slightly damp when shorn, and the weights have been corrected to allow for differing moisture contents at the two shearings, as far as possible, by making use of the woolstore weights of the wool, the average moisture content being taken to be the same for each in the store. Subsequently the moisture contents

of the medium crossbred bales were determined by the Department of Agriculture, Wellington, and the mean results were 14.17% and 13.86% for the August- and November-shorn wools respectively. Thus the difference was in fact small

TABLE 1. Fleece Data, 1953

	Pre-lamb-shorn			Post-lamb-shorn		
Date shorn	Aug. 24-5			Nov. 27		
Period of growth	54.6 weeks			53.5 weeks		
Class	Number	Weight† lb.	Length in.	Number	Weight† lb.	Length in.
AA Fine	16	7.4	6.1	9	8.1	6.5
A Fine	3	7.0	5.9	11	8.3	6.4
AA Medium	81	9.0	7.0	56	9.3	7.4
A Medium	24	8.5	6.9	33	9.4	7.4
AA Strong	14	9.1	7.6	13	9.7	7.9
A Strong	15	8.9	7.1	13	10.2	8.2
Total	153			135		
Mean		8.71	6.94		9.30	7.38
Skirted Fleece		6.89			7.38	
Pieces, etc.		1.82			1.92	

† From woolstore figures.

Fleece Results

Weight and Length

In the 1953 season the post-lamb-shorn fleeces were consistently rather longer and heavier than the pre-lamb-shorn ones, the average overall difference being 0.44 in. in length and 0.59 lb. in weight. Although these differences are in line with current opinion they could still be seasonal in origin and it remains to be seen whether they will in fact recur in succeeding years' clips from the same flock.*

It is interesting to note that the data also showed that the fleeces from the older sheep were rather lighter and shorter than those from the young sheep.

Quality and Grade

The total percentage of fleeces in each of the three wool qualities is almost the same for the two clips, as would be expected, but the relative proportions of AA and lower grade (A) fleeces are markedly different, there being more faulty fleeces in the post-lamb-shorn lot. The overall percentages of AA and A fleeces were as follows:

* In 1954 the average staple length in the two clips was the same but the pre-lamb-shorn fleeces averaged 0.7 lb. heavier than the post-lamb-shorn.

Grade	Pre-lamb-shorn	Post-lamb-shorn
AA	72.5	57.8
A	27.5	42.2

The faults that were recorded in the A fleeces in 1953 were as follows:

Pre-lamb-shorn	8 dingy, wasty, or poor colour
	5 soft cotts
total	13, or 8.5%
Post-lamb-shorn	24 tender (4 with colour also)
	7 cotted
	16 with colour
total	47, or 35%

Thus approximately four times as many fleeces in the second lot were recorded as having notable faults as in the first lot, while at the same time the faults in the second lot were of a more serious nature.

At shearing, the pre-lamb-shorn lot was the brighter in appearance and also rather looser on the average, while the post-lamb-shorn lot felt greasier and was slightly damp. When the pre-lamb-shorn was opened up after having been baled for 3½ months, it was found to have lost its initial brightness and then looked duller and dustier than the other lot.

APPRAISAL AND YIELDS

The two AA medium crossbred bales were exhibited at the December wool-sale in Dunedin by courtesy of Donald Reid & Co., and buyers were asked to comment on them and estimate the yields. The majority of the comments received were adverse to the pre-lamb-shorn wool while the mean estimate of yield was 2.0% lower for this lot than the other.

The two lots were sampled by the Department of Agriculture and the mean scoured yields found on the samples differed by only 0.3% in the same direction.

Subsequently the wools were scoured at a mill and the mill yields (card sliver and waste at 16% regain) differed by 0.6%, the actual yields being 77.9% and 78.5% for the pre- and post-lamb-shorn lots respectively. Thus the difference in the yields was appreciably less than was estimated by the buyers.

Small samples of wool were taken from every fleece at shearing-time and analysed in the laboratory. The mean results were as follows:

Shorn	Grease	Suint	Dry Wool
	%	%	%
Pre-lamb	5.3	7.6	67.6
Post-lamb	6.1	7.8	67.0

There was a consistent difference in grease content between the two lots within the various grades, and the grease content also showed a tendency to increase with age of sheep and with wool fineness. The suint and dry-wool figures did not show any of these trends.

MILL PROCESSING

The AA medium crossbred wools were used in a comparative manufacturing trial. These lots represented 43.3% and 33.0% of

the pre-lamb-shorn and post-lamb-shorn clips respectively after classing. The proportion of suitable wool in the latter was thus much less than in the former owing to the greater number of faulty fleeces in the latter.

Topmaking

The two lots (called "A" and "B" for pre- and post-lamb-shorn respectively) were sorted for quality, a small amount of stronger wool being rejected. They were not sorted for length as the fleeces were practically all of good combing length and it was desired to see what the effect of the difference in average length would be. Lot B was noticeably longer when handled both before and after scouring, and both lots appeared to be equally sound.

The wools were scoured in succession using a fresh liquor of Lissapol N (I.C.I.) and bicarbonate. The scoured wool was partly dried, and then carded at a rate of 35 lb. per hour. The card sliver and waste were weighed and their regains tested, as this was the most convenient point at which to determine the scouring yields, which have been given above. The percentage of card droppings and waste was exactly the same for both lots, being 5.5% of the scoured weight.

After backwashing and gilling, the two lots were combed on the same comb at a rate of 47 lb. per hour and the top, noil, and waste were weighed, and regains and oil contents determined. After allowing for variations in regain and oil content, the relative percentages of top, noil, and waste were:

	Lot A	Lot B
Top	95.0	95.0
Noil	4.3	4.2
Waste	0.7	0.8

There was thus a negligible difference between the two lots in carding and combing.

Drawing and Spinning

The tops were drawn on a crossbred drawing set and 5.5-dram rovings were made. These were spun mostly to 1/24s (Bradford worsted count), but a small quantity was spun to 1/25s and 1/22s, and doffs were also made with different twists and ratch settings. This experimental spinning was done on one side of a frame, 40 or 48 spindles being used for each lot and the ends down recorded. In order to see if there was any difference between the two halves of the side, the two lots were interchanged at one point without making any other alterations and the ends down again recorded. A difference was found but it was much less than the difference between the lots.

The number of ends down per 100 spindle-hours was consistently less for Lot A. The test results are given in Table 2.

It was found that Lot A gave the best spin at a ratch of $7\frac{1}{2}$ in. and Lot B at 8 in. The last two tests recorded were made on complete sides of slower frames and fewer ends down were recorded at the lower speeds. Subsequently the twist was increased on both frames by using a 46 wheel and the ratch for Lot A was set at $7\frac{1}{2}$ in., to give the best spinning conditions. The test data clearly show that the pre-lamb-shorn lot always gave the better spin.

TABLE 2. SPINNING TESTS

Test No.	Count wstd.	Twist wheel	Ratch in.	Ends Down/100 sp.hr. Lot A	Lot B
1	28	44	8	191	314
2	25	44	8	147	199
3	24	48	8	104	152
4	22	48	8	81	149
5	24	46	8	68	145
Frame ends interchanged					
6	24	46	8	80	125
7	24	46	$7\frac{1}{2}$	58	188
8	24	46	$8\frac{1}{2}$	134	154
Two sides of slower frames					
9	24	48	8	39	47
Frames interchanged					
10	24	48	8	53	63

TOP AND YARN TESTING

Tests on Tops

Measurements of fibre diameter (projection microscope), fibre length (comb-sorter and W.I.R.A. fibre-length machine), and drag (single-thread tester), were made on samples of top. The results of these tests are given in Table 3.

TABLE 3. TESTS ON TOPS

	Lot A	Lot B
Fibre diameter, microns	35.8	36.4
C. of V., %	26.7	25.9
Standard error, microns	0.41	0.40
Fibre length (comb-sorter), cm.	13.8	13.6
C. of V., %	35.0	38.0
Longer than 20 cm. (by weight), %	9.0	13.0
Fibre length (single fibres), cm.	10.66	10.20
C. of V., %	54.6	56.4
Standard error, cm.	0.16	0.15
Drag (after 2 weeks), oz./g.	3.31	3.28

There was no significant difference in fibre diameter, but Lot A was significantly longer than Lot B, and also rather less variable in length. Examination of the fibre length distribution diagram given in Fig. 1 and also the comb-sorter results, shows that the difference in variation was largely due to a higher percentage of the longest fibres in Lot B.

Thus although the average staple length in the greasy fleeces was longer in Lot B, the difference was not carried through to the tops, but rather was reversed. This suggests that more fibre breakage occurred in processing Lot B, i.e. that the wool was still slightly tender as compared with Lot A, or that it was more tangled owing to the more compact nature of the greasy fleeces.

There was no difference in drag between the tops two weeks after combing.

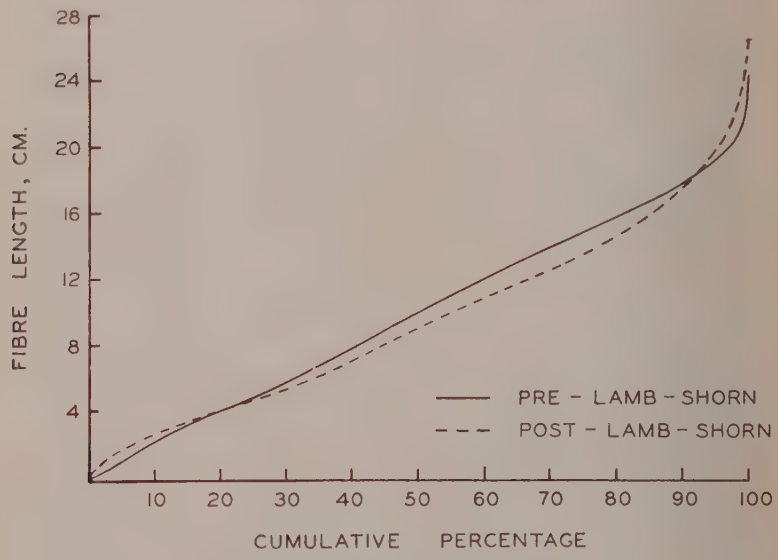

Fig. 1.— Fibre-length distribution in tops.

Tests on Yarns

Single-thread strength tests were made on 10 bobbins of each lot from spinning tests 2-9, and hank strength and count measurements on 40 bobbins each from test 2, 48 bobbins each from test 4, and 10 bobbins from each of tests 3 and 5-9. For the hank tests one 120-yd. hank was reeled from each bobbin on a 1½-yard swift, broken at a pulling speed of 4 in./min., and weighed. All tests were made in the conditioning-room at 70°F. and 65% R.H., and the count figures given are those obtained directly from the conditioned weights. The results of these tests are given in Table 4.

In all the tests but No. 8, the hank strengths and single-thread strengths and extensions of Lot A were higher than those of Lot B (in test 9 after allowing for the difference in count). The lower

TABLE 4. YARN TESTS

Spinning Test No.	Hank Tests				Single Thread Tests			
	Strength lb.		Count wstd.		Strength oz.		Extension %	
	A	B	A	B	A	B	A	B
1	Not tested							
2	37.9	34.4	25.2	25.0	5.3	4.9	12.5	10.0
3	36.6	32.8	24.6	24.2	4.9	4.8	12.8	11.7
4	42.9	39.5	22.2	21.9	6.1	5.5	12.6	10.1
5	40.5	34.3	23.7	24.5	5.7	5.1	13.0	11.7
Frame ends interchanged								
6	37.4	35.1	24.3	23.7	5.6	4.7	12.5	9.6
7	39.0	34.5	24.0	24.0	5.5	4.7	11.8	10.8
8	36.5	38.8	24.4	24.4	4.6	5.2	10.2	12.5
Two sides of slower frames								
9	36.6	34.9	24.8	23.5	4.9	5.1	11.2	10.6
10	Not tested							

A = Pre-lamb-shorn; B = Post-lamb-shorn.

strength of Lot A in test 8 was not unexpected as a poor spin had been obtained at the 8½ in. ratch used. In test 9 the spinning overlooker used one tooth different draft wheels for the two lots but the count determinations show that the same wheel was needed for both.

DISCUSSION

Greasy Wool

Fleece Length and Weights. The pre-lamb-shorn was slightly shorter in staple length in the 1953 season than the post-lamb-shorn, and the fleeces averaged slightly lighter in weight.

Grading. In the grading of the fleeces the pre-lamb-shorn lot was much superior as 72.5% were classed as AA, against 57.8% of the post-lamb-shorn.

Four times as many fleeces in the post-lamb-shorn lot were recorded as having notable faults, and at the same time the faults were of a more serious nature than in the pre-lamb-shorn lot.

Yield. The yields of the two lots of wool were little different, that of the pre-lamb-shorn being slightly the lower in the mill. The grease and suint contents found by analysis of staples also differed very little. This is contrary to the general opinion that the grease content of pre-lamb-shorn wool is low because "the grease has not risen".

The data show clearly that wool of superior grading is obtained by shearing before lambing because the time at which faults are likely

to develop then occurs shortly after shearing instead of some weeks before shearing so that the faults do not then occur at the more valuable butt end of the staples. This confirms the predictions made in Part I. Thus a higher proportion of sound combing wool is obtained by shearing before lambing. Correspondingly with longer wools a higher proportion of sound wool suitable for paper felts (commanding a premium in price) would be expected.

Mill Processing

Carding and Combing. There was no difference between the two lots in carding and combing, and the percentage of waste and noil was the same from each lot. The pre-lamb-shorn tops had the greater mean length and were also rather more uniform in length. There was no difference in drag between the tops two weeks after combing.

Spinning. The pre-lamb-shorn lot consistently gave the better spin as shown by fewer ends down. The yarns from this lot were consistently stronger than those from the post-lamb-shorn.

By classing and sorting, two equivalent lots of wool were selected. The pre-lamb-shorn lot, which formed a considerably higher proportion of its clip, was rather more open and appeared rather shorter in the grease. No difference in processing was detected up to the stage of tops, but the mean fibre length in the pre-lamb-shorn top was found to be longer, which probably indicates that more fibre breakage occurred in the other lot. There was no evidence that the openness of the greasy pre-lamb-shorn wool had any detrimental effect in processing, but rather the reverse, since it might be expected that this would lead to less fibre breakage. (It is hoped to investigate the question of fibre breakage with next season's clip.)

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